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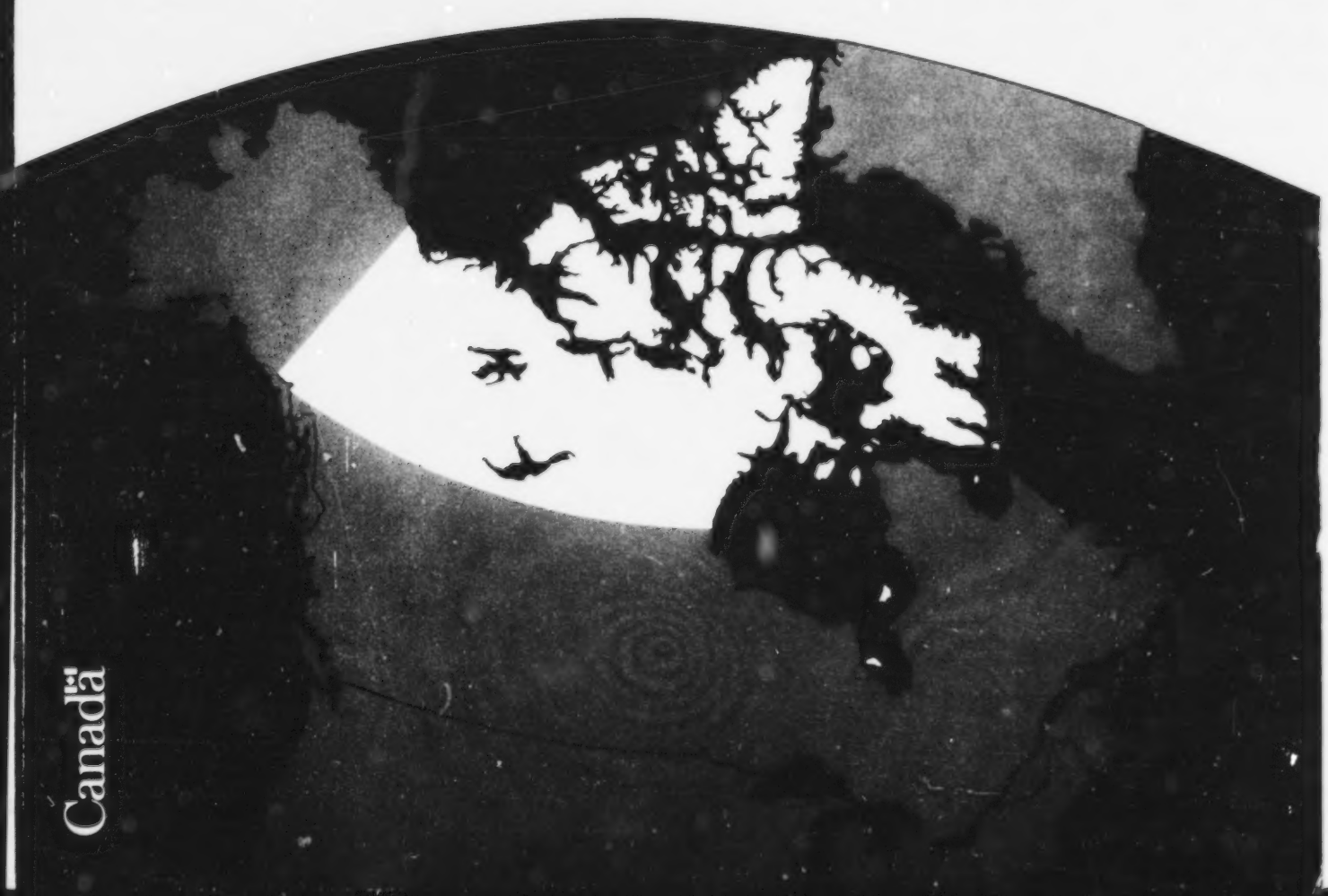
Environmental Studies No. 45

Investigation of the Magnitude and Extent of Sedimentation from Yukon Placer Mining Operations

Summary



Canada

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Investigation of the Magnitude and Extent of Sedimentation from Yukon Placer Mining Operations

Summary

Northern Affairs Program

Envirocon Limited

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RÉSUMÉ

Le présent rapport consiste en un examen général des activités d'exploitation des placers dans six bassins hydrographiques plutôt qu'en une étude approfondie d'un seul secteur minier. Cinquante et une mines ont fait l'objet de cet examen. Les données recueillies sur le terrain fournissent des renseignements sur les types de sol traités dans ces régions, les types et l'état des installations de sédimentation et la qualité de l'eau dans les cours d'eau récepteurs.

Exploitation des placers

Les conditions physiques variant d'une mine à l'autre, chaque exploitant y fait face à sa façon, selon son expérience et ses ressources. Le règlement des problèmes liés au traitement des effluents doit se faire en tenant compte des conditions particulières à chaque emplacement. Cependant, certaines caractéristiques sont propres à plusieurs exploitations:

1) Les bassins de sédimentation sont difficiles si non impossibles à maintenir dans les vallées étroites. Souvent, on ne dispose pas des pierres d'enrochement nécessaires pour protéger les barrages des bassins de sédimentation contre l'affouillement et le coût de construction de bassins pouvant résister à des crues éclair dans ces régions peut être trop élevé. En pareil cas, il serait peut-être plus économique de construire les bassins de sédimentation plus en aval, là où la vallée est moins étroite.

2) Même lorsqu'il s'agit de vallées de grande étendue, les inondations peuvent souvent provoquer l'ouverture de brèches dans les barrages des bassins, ce qui entraîne l'échappement de sédiments et peut réduire considérablement le volume utile du bassin. Le bassin doit être conçu de façon à pouvoir résister aux inondations.

3) Lorsqu'on a recours au décapage hydraulique, les installations de sédimentation doivent avoir la dimension requise pour pouvoir contenir la quantité prévue de morts-terrains. Ceux-ci doivent être entreposés dans une arrière-taille stable. L'utilisation de dispositifs d'aspersion pour

irrigation devrait être considérée comme solution de rechange au décapage hydraulique.

4) Le nettoyage des bassins de sédimentation n'est pratique que lorsque l'on dispose de l'équipement approprié et que le bassin a été conçu de façon à permettre un tel travail. À moins de pouvoir appliquer des techniques économiques de maintien des installations de sédimentation, l'on devrait construire un nouveau bassin lorsque celui-ci est plein et que les talus ne peuvent être élevés davantage. Il faudrait songer à trouver des moyens de stabiliser les matériaux fins recueillis dans les bassins de sédimentation avant que les placers soient abandonnés, que ce soit pour la saison ou en permanence.

5) L'utilisation de sources d'approvisionnement en eau ou d'installations de sédimentation communes devrait être envisagée lorsque deux exploitants ou plus travaillent l'un près de l'autre, surtout dans les vallées étroites. La photographie aérienne ainsi que des canevas planimétriques et altimétriques aideraient dans la planification.

6) La formation de glace peut constituer un problème, retardant les travaux et endommageant les ouvrages du bassin de sédimentation. Il nous faut plus de renseignements à ce sujet.

Sédimentation et qualité de l'eau

1) Les plus fortes concentrations de matières solides en suspension ont été enregistrées dans le bassin hydrographique de la rivière Indian, surtout immédiatement en aval des exploitations se trouvant sur le cours supérieur des ruisseaux Sulphur, Eureka et Quartz. Dans chacun des cas, on se servait de bassins d'emmagasinage et de sédimentation permettant de régulariser le débit du ruisseau.

2) Les bassins de sédimentation de quarante et un pour cent des mines faisant l'objet de l'étude étaient munis de multiples orifices de décharge des effluents, déversaient le trop-plein dans des bassins à stériles ou évacuaient les effluents par infiltration. La qualité des effluents émanant de ces installations a été déterminée en calculant la différence entre la qualité des eaux en amont et en aval de la mine à l'aide de paramètres établis.

Puisque dans la plupart des installations de sédimentation examinées dans le cadre de l'étude on a constaté des fuites par infiltration, il faudrait remettre en question la pertinence des règlements fondés sur les normes de qualité des effluents.

3) L'efficacité de vingt-huit des cinquante-deux installations de sédimentation examinées pouvait être mesurée ou estimée. On a déterminé que douze des vingt-huit installations, soit environ 40 p. 100, étaient efficaces (la norme de 0,2 ml/l de matières solides décantables fixée relativement au taux de sédimentation ayant été respectée).

4) Certaines des installations les plus efficaces avaient été conçues de façon à ce qu'une proportion élevée des eaux contenant des stériles soit déversée directement dans la nappe souterraine. Il faudrait déterminer si des matériaux convenables sont disponibles dans d'autres régions, l'utilisation de ces matériaux pouvant permettre d'améliorer la qualité des effluents.

5) Les concentrations de résidus non filtrables étaient comparativement basses ou négligeables dans les affluents où l'on ne trouve aucun projet industriel. À moins que l'on ait besoin de données très exactes ou complètes sur la provenance des sédiments, on peut faire abstraction des sédiments provenant de ces affluents.

6) Les cours d'eau traversant des régions déjà exploitées telles que la partie supérieure du ruisseau Barlow (aire de drainage du ruisseau Clear) et la partie inférieure du ruisseau Allgold peuvent renfermer d'importantes quantités de matières solides dues à l'érosion. Dans le cadre d'études ultérieures, l'on devrait prendre en considération la présence possible ces sédiments.

7) Les observations et les analyses faites sur le terrain quant à la variabilité de la qualité des eaux démontrent que d'importantes variations spatiales et temporelles peuvent se produire dans les cours d'eau où l'on exploite des placers. On ne peut trop mettre l'accent sur l'importance de ces variations qui devraient être prises en considération dans le cadre d'études ultérieures.

1.0 CONCLUSIONS AND RECOMMENDATIONS

The program represents an extensive investigation of placer mining activities in six watersheds rather than an intensive study of a single mining area. Fifty-one mines were reviewed during the study. Field data collected provides information regarding the types of soils processed in these areas, types and status of settling facilities and water quality throughout the receiving streams.

1.1 Placer Mining Processes

An outstanding feature of the placer mines studied is their diversity. The physical conditions are different at almost every operation. Each placer miner has reacted to these conditions in his own way depending on his experience and resources. There is no such thing as a "typical placer mine". Final resolution of effluent treatment problems must be site specific. There are some features common to a number of placer operations.

1) In narrow valleys it is usually impossible to establish and maintain settling ponds which will function as intended for any appreciable length of time. The settling pond dam must extend across the valley and as a result control the entire flow of the stream. In periods of high water, these dams are usually washed out or breached, releasing large volumes of sediment-laden water to the valley below. Although it may be possible, in some cases, to protect the dams with rip-rap, suitable material is often not available.

   The expense of building settling ponds capable of withstanding flash floods for miners operating in narrow sections of a watershed (usually near the headwaters) may be prohibitive. Locating settling ponds further downstream where the valley is wider appears to be a more cost effective solution.

2) Even in wide valleys where space is not limiting, settling ponds are not built to withstand floods. Breaches in settling pond berms result in the release of previously settled material and, if not repaired, significantly reduce the effective volume of the pond. The hydrology of floods in small Yukon watersheds must be better understood to allow the design of settling facilities that can withstand flash flood conditions.

3) Where muck is shallow (up to two or three metres) it is usually stripped with heavy equipment. In areas where the muck is six metres or more in depth, stripping with heavy equipment is usually not practical. In such cases hydraulic stripping is used and the muck is washed down the valley. When hydraulic stripping is practiced, settling facilities must be large enough to contain the expected quantity of muck. Muck should be stored in stable waste areas to minimize entry of this material into the receiving stream.

4) Hydraulic stripping was practiced at many of the mines visited during this study. An alternative method of stripping muck using irrigation sprinklers should be considered. This method could result in faster stripping, more efficient use of water, less cost and improved performance of settling facilities. It must be noted that sprinkler stripping may not be suitable for some locations.

5) Following the mining season, settling ponds are usually drained in an attempt to minimize damage during spring floods. It is expected that much of the material that has collected in the pond during the mining season is washed downstream as a result of draining the pond. The trapped sediment is subject to erosion and may continue to contribute to downstream sediment loading until the settling pond is put back into service. Consideration should be given to methods of stabilizing the

fine material collected in settling ponds before mine sites are abandonned for the winter.

6) Cleaning out settling ponds is only practical with appropriate pond design and equipment. Unless cost-effective technologies for maintaining settling facilities can be developed, when a pond is full and where the berms cannot be built higher, a new pond should be constructed. All possible measures should be taken to ensure the abandonned pond's stability to avoid erosion of previously settled materials.

7) In cases where a single pond is used for both storage and settling and regulates most, if not the entire creek flow, rapid openings of the control structure will cause significant increases in downstream flows containing large quantities of suspended sediment. Downstream settling ponds may be overloaded under these conditions as retention times are reduced.

8) Where there are two or more operators working fairly close together, the possibility of establishing a communal water supply and/or settling facilities should be considered. This may be very beneficial to operations in narrow valleys that do not have enough space on their own property to establish adequate settling facilities. In some cases, up-to-date aerial photography with horizontal and vertical ground control would assist in planning. A reasonable level of cooperation on the part of the miners would be required to achieve success. There may be some merit in a formal agreement among the miners with respect to communal treatment facilities, including compensation for members who expended time on the construction and maintenance of the facility. All miners would benefit to varying degrees.

9) Many operators reported having problems with glaciers. The glaciers not only delay mining operations, but can damage settling pond structures. A better understanding of glacial processes would assist in the location and design of stable settling ponds.

1.2 Sedimentation and Water Quality

1) The largest concentrations of suspended sediments were observed in the Indian River watershed. The largest concentrations in each of Sulphur, Eureka and Quartz Creeks were recorded just downstream of mines operating in the headwaters of these creeks. Each of these operations were using a combined storage/settling pond facility which was able to regulate the total creek flow.

2) Forty-one percent of the mines visited during the study (excluding the six operations with total recirculation) did not have a single effluent stream that could be directly sampled. Many of the settling ponds had multiple outlets, overflowed into tailings or discharged by seepage. The water quality of the effluent from these facilities was determined by calculating differences in selected water quality parameters upstream and downstream of the mine. This approach is less accurate than measuring the mine site effluent directly because physical processes other than the mining activity may modify water quality between the upstream and downstream sampling sites.

As most of the settling facilities examined during this study had some seepage discharge, the appropriateness of regulations based on effluent quality standards should be reconsidered. If there is no direct discharge from the settling facility, or if only a fraction of the effluent is discharged directly, basing the standards on effluent quality, may not provide an appropriate level of protection to receiving streams.

3) Efficiencies of twenty-eight of fifty-two settling facilities studied could be measured or estimated. Twelve of these twenty-eight (approximately 40%) were determined to be effective (based on achievement of the current effluent quality objective of 0.2 ml/l settleable solids concentration).

4) Some of the most effective settling facilities were designed to discharge a large percentage of the tailings waters directly to the groundwater system. A study of the availability of suitable materials in other areas and their application could result in improved effluent quality.

5) Non-industrial tributaries had comparatively low or negligible NFR concentrations at this time of the year. Therefore, unless extreme accuracy of results, or thorough documentation of all sources of sediment input is required, the sediment input from non-industrial tributaries can be ignored.

6) Water courses flowing through previously mined areas such as upper Barlow Creek (Clear Creek drainage) and lower Allgold Creek may contain significant sediment loads resulting from erosion. The potential for contribution of sediment from these areas should be included in the design of future studies.

7) Field observations and analysis of the variability in water quality results demonstrate that large spatial and temporal variations in water quality parameters can occur in mining streams. The magnitude of this variation can not be over emphasized, and should be considered in the design of future studies.

1.3 Recommendations for Future Studies

Section 1.3.1 presents recommendations for future studies and Section 1.3.2 identifies a watershed suitable for future intensive investigation.

1.3.1 Future Studies

1) Future, intensive studies, should span the duration of the mining season to account for day-to-day variations in the level of mining activity. It is not possible to determine from this study if particular results occurred because of extreme events or whether they are routine occurrences.

2) In this study emphasis on the use of a stream reach approach required that the automatic samplers be located predominantly in the receiving waters of the watershed rather than around individual mining operations. If in future studies, a greater emphasis is placed on inputs from a particular mining operation, the automatic samplers should be installed on the mine's inflow and effluent streams as well as immediately upstream and downstream of the operation.

3) This study found that most operators had a fairly good idea of their activities in a general sense but did not keep detailed records of events. Often processing was terminated due to breakdown and the operator was more concerned about becoming operational than noting the amount of time lost due to the breakdown. To collect the detailed information required to prepare an accurate mass balance requires mine site data be collected continuously, for the period of the study.

4) Efficiency and reliability of the automatic water samplers is extremely important to projects where water quality sampling is a major component. Several different types of samplers were supplied, and it was found that all but one type operated inefficiently or not at all. It is recommended that only automatic samplers with proven reliability be used in future studies.

5) To obtain an accurate understanding of the sediment loading to a particular receiving stream, both continuous water sampling and continuous flow measurement would be required. If this level of detail with respect to sediment loadings is deemed necessary to determine the impact(s) of placer mining on aquatic habitats, both water quality and flow rate must be measured over an extended period of time. This level of instrumentation could probably only be justified in a detailed examination of a single test watershed.

6) Installation of the automatic sampler intakes was often time consuming because of the care taken to achieve proper placement and ensure that the water samples taken would be as representative of stream conditions. Placement of these intakes is a concern whenever automatic samplers are used. If automatic samplers are to be used in future, it would improve field operations and help provide consistent automatic sampling if a special sampler intake head was designed that could be used with each sampler. The sampler intake head should be designed to support the intake off the bottom of the stream and be heavy enough to keep the intake in position.

1.3.2 Suggested Drainage for Future Studies

This study was an extensive review of six watersheds and would best be followed by an intensive study of one or possibly two watersheds . An appropriate watershed should have:

(i) numerous mines;
(ii) diversity of type of mining operations;
(iii) diversity of size of mining operations;
(iv) a watershed size that allows continuous sampling throughout the watershed for the entire period of study;
(v) good access to sampling sites;
(vi) close proximity to scheduled transportation to ensure regular shipment of samples.
(vii) environmental sensitivity; and,
(viii) availability of background information.

Experience gained during the field program and review of the above criteria suggests that one of the sub-drainages of the Indian River watershed would be most suitable for further in-depth studies.

An intensive study of the Dominion Creek drainage, downstream to immediately above the Sulphur Creek confluence, could be undertaken with a crew of four. Ideally the study would span the entire mining season (June to mid-September). A sufficient number of automatic water samplers and continuous water recorders would be required to monitor the effluent of each active mine and to collect data at the reaches used in this study. Flow and sediment contribution from non-industrial tributaries and industrial streams above operating mines should be sampled at a frequent enough interval to account for natural variability.

2.0 STUDY DESIGN

This document summarizes the results of an eight week field program undertaken in August and September of 1985. This study reviewed placer mining operations in seven watersheds of the Yukon Territories (Figure 2.1) and measured the concentrations of suspended and settleable sediment in water courses in the vicinity of these operations. The mining operations studied were located in the Clear Creek, Allgold Creek, Haggart Creek, Sixty Mile River, Indian River, South Big Salmon River and Kimberly Creek watersheds. Mines ranged in size from small, one-man operations to very large operations. Types of operation, level of activity and gold recovery processes were often defined by site-specific constraints, available equipment and/or operators' experience.

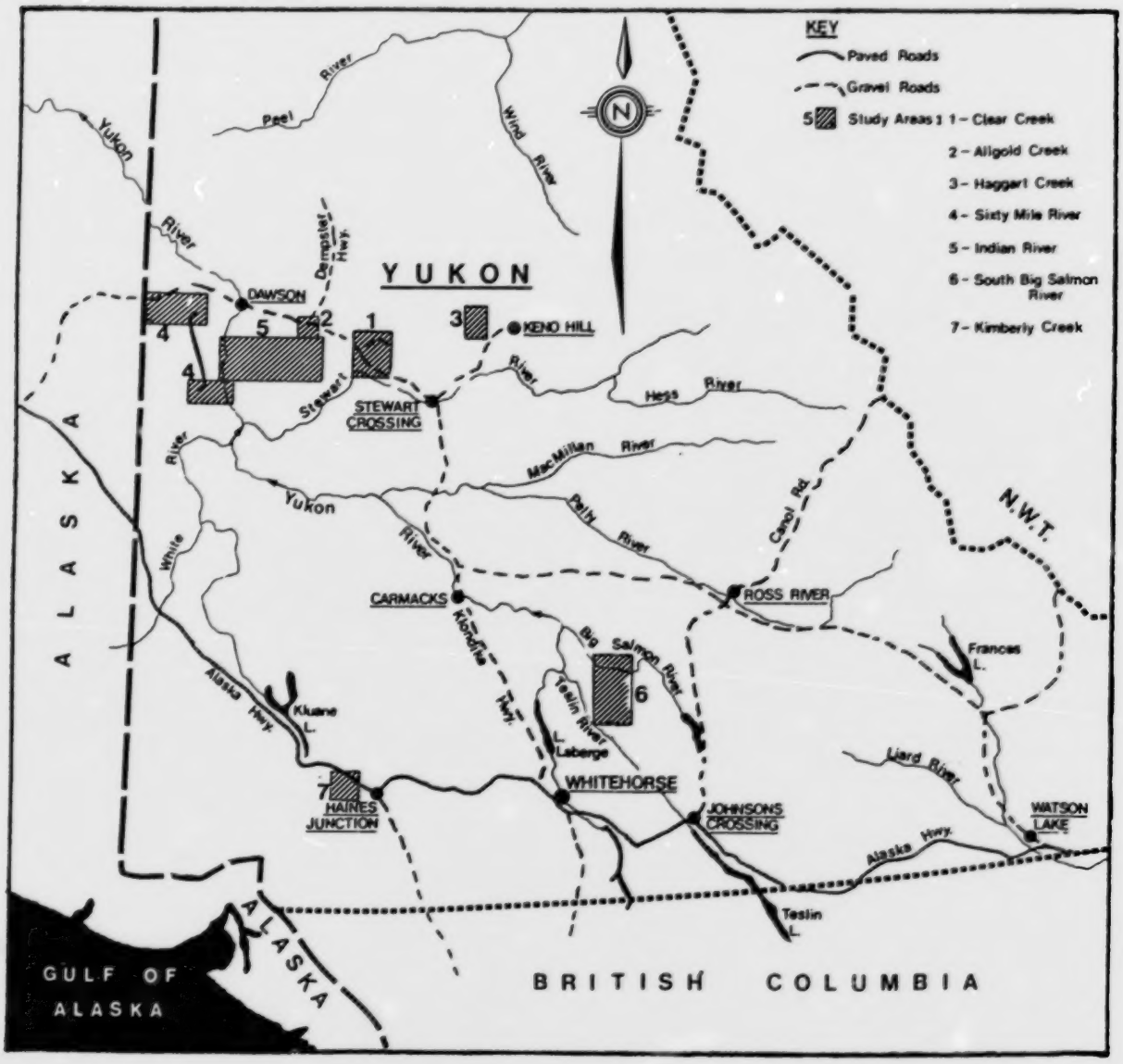
Information and data relating to this study is presented in two volumes. The first volume contains the text of the report, including site location maps. The second volume contains Appendices A, B, C, D, E, F, G, H and I.

Ninety-eight active placer mining operations were identified at the start of the study. Mines where the operator was not present and those where the operator requested that data not be collected are not assessed in this study. Included in the mines visited was a dredging operation on Clear Creek.

During each mine-site visit, data were gathered to gain an understanding of the type and size of operation, the types of soils processed, and the quality and quantity of water entering the operation and subsequently being discharged. Information collected during this study is used to assess the incremental effect of mining operations on downstream water quality.

FIGURE 2.1

LOCATION MAP



3.0 PROJECT OBJECTIVES

The objectives of this study were to gather information on the concentration of sediments discharged to Yukon streams as a result of placer mining operations and to provide a profile of the origin of sediment, how it was treated during placer mining operations, and the fate of sediment after discharge. Problems and constraints, with respect to the treatment of mine effluent, that miners encountered within their operations were to be identified and recommendations made for improvement of effluent treatment.

The program was designed to be an extensive investigation of seven watersheds rather than an intensive study of a specific mining area. As a result, the data gathered provide a "snapshot" of events.

The study focused on three concerns relating to the production and distribution of suspended sediments in the aquatic environment. Specifically, the three subjects examined in this study are:

(i) the processes used in placer mining (to determine the amount of suspended sediment entering the effluent treatment facilities);

(ii) the concentrations and quantities of settleable solids and suspended sediment discharged from the mine site to the receiving waters, and

(iii) the downstream distribution of settleable solids and suspended sediment as they relate to distance, flow and tributary inflows.

The terms of reference were:

(i) to summarize and interpret settleable solids and suspended sediment concentrations and sediment loadings by stream reach for each mine and natural sediment source measured;

(ii) to describe active mining operations and present opportunities for effluent treatment improvements;

(iii) if possible, to perform a materials balance calculation to estimate the effect on downstream water quality of effluent improvement; and,

(iv) to summarize and discuss substrate analyses as they relate to the potential impact of sediment deposition of fish habitat.

Specific tasks identified in this study design include:

(i) placement of automatic water samplers on a stream reach approach to provide information to determine sediment loadings in the receiving waters over the duration of the study within each identified watershed;

(ii) determination of flow and sediment contributions from tributary streams to enable a comparison of sediments from industrial and non-industrial sources;

(iii) provide an estimate of variability of sediment levels over the period of sampling;

(iv) obtain sediment samples in the main receiving water courses of each watershed to provide an indication of differences in water quality;

(v) in addition to settleable solids and non-filterable residue (NFR) concentrations, analyze water samples for turbidity, pH and volatile non-filterable residue (VNFR);

(vi) provide, in a rigourous and consistent manner, an evaluation of each mine site including: measure flows in the treatment system, measure pond volume, detail flow routings, estimate pond retention time, note amount of overburden and pay material moved daily, note material preclassification techniques and take samples from the material entering the sluice, and analyse for grain size distribution, and note operating and sluicing schedule to aid in interpretation of effluent and receiving water quality data;

(vii) identification of treatment problems and opportunities for improvement, evaluated as quantitatively and systematically as possible while allowing for innovative approaches;

(viii) two additional visits to Clear and Allgold Creek watersheds to collect additional water samples and document the substrate at six representative riffle sections (ten replicate substrate samples at each site) comprising good fish habitat in each of the two watersheds, and analyse by standard seive techniques to provide identification of the clay, silt, sand and gravel fractions; and,

(ix) appropriate analytical quality control measures to ensure the repeatability of the non-filterable residue analysis.

4.0 DISCUSSION

Mining activities in each of the watersheds studied were varied, ranging from, small operations near the headwaters to much larger operations downstream in the wider area of the valleys. The type of operation, quantity of pay gravel processed, type of settling facilities and their effectiveness, and the resulting effect on downstream water quality were dependent on physical constraints and availability of water at each particular mine site.

Six watersheds in the Dawson, Mayo and Whitehorse Districts were studied. Mining on Kimberly Creek had ceased prior to the period scheduled for study of operations in that watershed. Fifty-one of the ninety-eight identified as active mines were reviewed. Active mines were defined based on the existance of a current water-use permit. The most active area, in terms of number of operating mines, was the Indian River watershed. For logistical reasons this watershed was divided into four sub-drainages. Although somewhat smaller, the Sixty Mile River watershed was the most diverse with respect to the type and size of operation. Operations in other watersheds, such as Allgold Creek, Haggart Creek and South Big Salmon River were smaller and less diverse in character.

Settling Facilities

Several types of effluent treatment methods were used by miners to control the quantity of suspended sediment entering downstream water courses. The most common of these was the settling pond, created by constructing an earthern berm with either an over-berm outlet structure or groundwater seepage. The other common method was to discharge tailings water to large areas of gravels and/or tailings (in many cases, dredge tailings) from previous mining operations where sediments were removed as the tailings percolated through the soil.

Others used combined storage/settling ponds which in some instances regulated most, if not all, of the water course. Operation of some of these combination ponds were observed to have significant effects on downstream water quality.

The effectiveness of the facilities observed during the study period was determined by several factors including size, location, type of discharge (e.g. overflow structure or seepage), current status (some settling ponds were full), maintenance, types of pay materials being processed, rate of loading, volume of organic overburden being hydraulically stripped (some operations were hydraulically stripping large amounts of muck) and operation of control structures.

In some instances short term or cyclical increases of settleable solids concentration, above average values, were recorded below the discharge of settling facilities that appeared effective. This likely resulted from short term modification to normal operational procedures which introduced a surge of flow to the settling facility. The efficiency of settling ponds decreases under surge conditions as the retention time of the pond is temporarily reduced.

Currently the Yukon Territory Water Board suggests that placer mines meet a settleable solids objective of 0.2 ml/l for their effluent discharge. During this study water samples were collected, where possible, from the point of discharge of settling facilities. These data are limited as many facilities had no obvious single point of discharge to the receiving water. Of the settling facilities' discharges that were sampled, approximately 40% met the 0.2 ml/l objective.

Some operators were concerned with the poor performance of their upstream neighbours' settling facilities. The miners with no upstream neighbours often complained about silt and mud in the creek during high runoff periods in the spring and during flash floods. While many miners conceded that settling ponds

were a good idea, others questioned their long term value and considered them a nuisance.

Suspended Sediments

Levels of suspended sediment detected throughout each of the watersheds were proportional to the activity and type of flow regulation at the various mining operations. Suspended sediment inputs from non-industrial sources in all watersheds were negligible or very small when compared to industrial inputs.

To calculate sediment loadings, sediment concentration (NFR in this study) and water flow rate are required. At most locations studied, both these parameters were measured. Although continuous automatic water samplers were installed at various locations along each of the creeks and streams, flows were not metered continuously. Thus, the calculated suspended sediment loadings are only truly representative of the time of the flow meterings.

However, the effects of changes in mine operating conditions, for example the release of water and sediment from a combination storage settling facility, can significantly alter the rate of both water flow and sediment discharge in the system. In other cases, the rate of travel of discontinuities in either sediment input or flow over long distances within watersheds (such as the Sixty-Mile River) must be considered. These discontinuities can only be accurately recorded by the continuous recording of both water flow and sediment discharge and/or sampling over long periods of time to ensure that observed input or flow events have passed by sequential recording stations.

As this study was designed to be an extensive investigation of seven watersheds rather than as intensive single site study, the recording of sediment concentrations and the point measurement of flows were conducted over limited

time periods. If flow and suspended sediment concentration are constant over the sampling period, the calculated suspended sediment loading will be accurate. However, if either (or both) flow and NFR concentration vary over the sampling period, the accuracy of calculated suspended sediment values will be limited by how closely the measured flow and concentration data represent actual conditions. In the case of rapid short-term changes in flow and suspended sediment concentrations, accurate estimates of suspended sediment loadings may not be possible. This is the case in situations where it was evident that settling ponds were "flushed" resulting in large, short-term increases in both suspended sediment concentrations and flow. To accurately estimate suspended sediment loadings under such conditions requires that the sampling interval be of a duration that is shorter than the pertubation. In situations of gradual changing flow or concentration the assumption of constant conditions may be valid and allow the calculation of suspended sediment loading. The available flow and concentration data for each automatic sampler location was assessed before suspended sediment loadings were calculated. These data defined analyses periods for which suspended sediment loadings were calculated.

A series of maps has been included following Section 4.6 and provide a summary of sampling sites and water quality sampling results. These maps show the location of each watershed in relation to its main receiving stream, locate all active mine sites that were visited, display the results of water samples taken by the automatic samplers (means and ranges of NFR and settleable solids concentrations) and display values of calculated suspended sediment loadings at various locations throughout each watershed. Maps detailing mine and sampling sites are presented at a larger scale than maps of the overall watershed. For example the location of Clear Creek in relation to Stewart River (its main receiving water course) is presented in Figure 4.1. Actual sampling locations are detailed in Figures 4.2(a), (b) and (c). For simplicity, these figures are referenced as a non-subscripted number (eg. although a mine on the left fork of Clear Creek is presented on Figure 4.2(a), the reader is referred to Figure 4.2).

The suspended sediment loadings calculated for the metered tributaries upstream of mining operations provide a good indication of inputs from non-industrial sources. The majority of suspended sediment concentrations and loadings measured in the receiving waters were observed to originate from the active placer mines operating on these streams and/or their tributaries.

The grain size distribution of paydirt samples provides an indication of the types of soils processed at a specific mine site. The larger fractions of the tailings are usually disposed of by machine and stored in piles away from current operations. The finer suspended materials usually enter a drain system leading to settling facilities. Depending on the current state of the settling facilities, a proportion of these fines are removed prior to discharge to the receiving stream. Clay and some silt sized particles usually pass through the settling facilities and stay in suspension in the receiving waters for varying distances downstream. The majority of soil samples collected from the mines contained less than 15% silt and clay sized material (smaller than 0.067 mm) and less than 2% clays (smaller than 0.002 mm).

In some cases, sediment loading in the discharge from settling ponds was high. This usually resulted from the pond being nearly full with sediment, and/or erosion of the overflow structure. The efficiency of such ponds could be increased by cleaning out the pond(s), increasing their volume by building up the existing berms and/or modification of discharge structures. An alternative is the abandonment of the existing ponds and construction of new ones.

Pay gravels in most mining areas were covered with varying amounts of organic overburden (muck). In many cases this muck was shallow enough that it could be mechanically stripped and moved to the side of the valley away from the stream. In areas where the muck was deep, it was usually hydraulically stripped, adding significant loadings to the settling facilities and/or receiving stream.

A method of stripping this muck with standard irrigation-type sprinklers was developed more than twenty years ago on Dominion Creek. It was reported to be very effective in both cost and use of water. As this technology appears to be unknown to the miners in the study area, documentation of the technique has been included in the report (Appendix G). This method of stripping muck could be of considerable advantage to the operator because of faster stripping, lower labour and fuel requirements and more effective use of available water. In addition, the slurry discharged to the settling facility has a lower water content than with other methods of hydraulic stripping. This should result in more complete settling and easier pond maintenance.

In several watersheds, where mines were operating near the headwaters, concentrations of NFR were high. However, NFR loadings were relatively low in these areas due to the low flows. These high concentrations were frequently observed to decrease downstream, partly to settling, but primarily to dilution from increased non-industrial tributary inflows.

Concentrations of NFR and suspended sediment loadings were observed to vary in response to mining operations. Values of these parameters typically increased immediately below industrial inputs and then decreased downstream. The rate of decrease in NFR below industrial inputs was dependent on the amount of dilution from increased non-industrial inflows, stream velocity and length of stream over which the suspended material could settle prior to input from an additional industrial source.

With the exception of Sixty Mile River and Haggart Creek, NFR concentrations in water samples collected near the mouth of the mainstem water courses in each watershed were higher than NFR concentrations in their receiving streams. Concentrations of NFR at the mouth of Sixty Mile River were approximately half the concentration recorded in Yukon River. Concentrations of NFR in Haggart Creek and South McQuesten River appeared to be similar.

In the following sections, water quality results are discussed separately by watershed. Where valid, comparisons of sediment loading rates are discussed. Otherwise, comparisons between locations are limited to discussion of NFR data.

4.1 Clear Creek

Six of the nine active mines in the Clear Creek watershed (Figures 4.1 and 4.2) were visited during the field program. These included one operation on the upper left fork, one on the lower left fork, one on 65 Pup, a tributary to the left fork, one on the right fork, one on the mainstem below the forks' confluence and one on Barlow Creek, a tributary to the lower portion of the Clear Creek drainage.

The mines located at the upper end of the left fork and on 65 Pup were operating within narrow valleys near the headwaters of their respective drainages.

Mines on the lower left fork, on the right fork, on the mainstem downstream of the left and right forks' confluence and on Barlow Creek were situated in wider sections of the valley bottom.

Settling facilities used in this watershed consisted of one or more ponds with seepage and/or over-berm discharge. The series of settling ponds below the dredging operation on the right fork was observed to be effective. The nature of the dredging process resulted in large quantities of gravel being deposited in berms across the creek creating a series of settling ponds as the operation proceeded upstream.

None of the mines on the left fork had effective settling facilities. Settling ponds in the mine below the left and right forks were essentially full, providing little if any settling. The mine operating on Barlow Creek was partially recirculating the process water. Its settling facility was judged to be ineffective.

Due to difficult road access, this watershed was divided into upper and lower drainages. Sampling periods in each sub-drainage provide an indication of water quality changes within each sub-drainage but are not continuous enough to provide sequential records between drainages. Water quality results presented in Figures 4.2 (b and c), downstream of Squaw Creek, do not necessarily represent the effects of sedimentation inputs from the upper drainage.

Water quality in the left fork changed noticeably from background levels in response to the mining operation in the upper end. Both NFR concentrations and suspended sediment loadings were increased downstream of this operation (Figure 4.2).

Two additional mines were active on the left fork (on 65 Pup and downstream near the mouth of Barney Creek). Magnitudes of NFR concentrations and suspended sediment loadings increased above the confluence with the right fork. Suspended sediment loading in the right fork was extremely low above and below the single mining operation.

Downstream of the mine situated 3.5 km below the confluence of the left and right forks, suspended sediment loadings increased substantially as a result of mining activities. It is expected that the amount of suspended sediment would have decreased with distance (as occurred on the left fork) as no industrial inputs were present above Barlow Creek, approximately 20 km downstream. In addition, NFR concentrations in this section of the creek were diluted by relatively large inflows from Squaw Creek. Although mining had previously occurred in Squaw Creek, the amount of suspended sediment was low.

Suspended sediment loadings in Clear Creek were increased due to inputs from mining activities on Barlow Creek. Both NFR concentrations and suspended sediment loadings in Clear Creek near the mouth were observed to be higher

than those measured upstream of Barlow Creek. These concentrations of NFR were much higher than those contained in a sample collected from the Stewart River above Clear Creek.

Concentrations of NFR recorded during the second and third visits were lower than concentrations recorded during the initial visit.

4.2 Allgold Creek

The single active mine visited is located near the headwaters of Allgold Creek (Figures 4.3 and 4.4). The treatment facility at this mine consisted of a single settling pond created by pushing up gravel berms and included an overflow structure. Although no sluicing was being carried out during the site visit, this large settling pond should have been effective.

Although some sediment was entering Allgold Creek as a result of stripping activities at this mine, the majority of the suspended sediment entering Flat Creek from Allgold Creek, appeared to originate from abandoned mine sites located in the downstream reaches.

Concentrations of NFR in samples collected throughout the watershed during two later visits were lower than concentrations recorded during the initial visit.

4.3 Haggart Creek

Nine active placer mines were identified and three were working at the time of the field program in this watershed (Figures 4.5 and 4.6). The three mines visited were operating on Haggart Creek and two tributaries. The most upstream mine visited was on Dublin Gulch. The other two were on Haggart Creek below Dublin Gulch and on 15 Pup, approximately 2.3 km downstream.

The settling facilities in the Haggart Creek watershed were among the most efficient observed during the study. This was primarily due to the abundance of old mine tailings readily available for pond construction. Discharge to Haggart Creek was almost entirely by seepage through these gravels.

Comparatively large concentrations of suspended sediment in Dublin Gulch and Platinum Gulch entered Haggart Creek as a result of mining activities. However, flows in these industrial tributaries were much lower than the flow in Haggart Creek. Consequently, the NFR concentrations in Haggart Creek below these mines were only slightly higher than background levels.

Mining operations on 15 Pup appeared to have little effect on water quality downstream. The suspended sediment concentrations in water samples collected in Haggart Creek below 15 Pup were lower than in samples collected upstream. Non-industrial sources accounted for very little of the suspended sediment loadings in the upper reach of Haggart Creek near the three mining operations.

4.4 Sixty Mile River

Fourteen of the nineteen active mines were working in this watershed (Figures 4.7 and 4.8). The majority of placer mining activity existed in the upper portion (upper drainage) of the Sixty Mile River watershed around the old town of Sixty Mile. All mines were either on tributaries or the ditch and drain system developed adjacent to Sixty Mile River and below Miller Creek. One active mine in the lower drainage was located on Ten Mile Creek which enters Sixty Mile River approximately 20 km upstream of Yukon River.

Due to the size and level of mining activity, sampling in this watershed extended over an eight-day period. Logistically, the entire watershed could not be studied in one sampling period, and therefore four study segments were used for water

quality analyses. Segments A, B, C and D are identified in Figure 4.8. It must be noted that, due to limitations of available data, the period of record for these study segments are not sequential.

The large communal settling pond at the bottom end of the ditch and drain system was used in varying amounts by five mines. During the site visit, this facility was essentially full and providing little or no settling. The primary ponds in most, if not all, mines on the ditch and drain system were not operating effectively. The facility near the headwaters of Miller Creek was the only one in this watershed operating effectively.

Discharge from the settling facilities operated by individual miners occurred via over-berm discharge structures, seepage through berms and ground seepage through old dredge tailings. Maintenance of ponds consisted of pond enlargement or modification of berms to increase effective pond volume.

Significant concentrations of suspended sediment were recorded below the mine on Bedrock Creek at the upstream end of the upper drainage. However, dilution from tributary inflow and settling along approximately 6 km of the Sixty Mile River resulted in very low levels of NFR concentration just upstream of the Sixty Mile River/Miller Creek ditch and drain system.

The mine near the headwaters of Miller Creek did not add significantly to suspended sediment levels. However, mining activity farther downstream supplied appreciable amounts of suspended sediment to Miller Creek and subsequently to the Miller Creek drain. The five mines within the Sixty Mile River/Miller Creek ditch and drain system added significant amounts of suspended material to Sixty Mile River as the large communal settling pond was observed to be essentially full. In addition, approximately half the flow in the Sixty Mile River ditch by-passed this large facility and entered Sixty Mile River

further downstream. Concentrations of NFR in the discharge from the large communal settling pond at the bottom of the Sixty Mile River/Miller Creek ditch and drain system were much higher than those measured upstream in Sixty Mile River.

Four of the five miners operating in this area were stripping moderate to large amounts of muck. The mine at the top of the Miller Creek ditch was stripping mechanically. Water samples collected in this area indicate 5 to 10% of the suspended material were organic. The mine at the top of the Sixty Mile River ditch was stripping barren gravel and moderate amounts of muck. Most of the muck went directly to the settling pond. A sample of this muck was analysed for grain size distribution and contained 67.5% fine grained material (less than 0.063 mm) of which 7.5% was of clay (less than 0.002 mm).

Mines on tributaries to Big Gold Creek (Little Gold Creek and Glacier Creek) added large quantities of suspended sediments to their receiving waters. Samples taken from Big Gold Creek below these tributaries showed that the suspended sediment concentrations were significantly reduced, especially below Little Gold Creek. The majority of this reduction was due to dilution by the Big Gold Creek flow.

Analyses of water samples taken in Sixty Mile River below Big Gold Creek showed increased levels of suspended sediments in response to inputs from Sixty Mile River, the ditch and drain system and Big Gold Creek. The mean and range of the suspended sediment concentration were reduced compared to values observed in the industrial tributaries. Water quality in Sixty Mile River for the next 100 km is not affected by industrial tributaries.

Mining activities on Ten Mile Creek in the lower drainage supplied two peak loadings to the creek. Some of this material would be expected to settle out in

the approximate 3 km to the mouth of Ten Mile Creek. Samples collected downstream near the mouth of Ten Mile Creek contained much higher suspended sediment concentrations than samples collected in Sixty Mile River. Inputs from Sixty Mile River were observed to have little effect on Yukon River approximately 20 km downstream.

4.5 Indian River

Forty-one active mines were identified in the Indian River watershed and twenty-four of these were working during the field program (Figure 4.9). Water quality in Indian River was significantly affected by inflow from Dominion Creek and Sulphur Creek, the two largest industrial tributaries. In recognition of the influence of these two inputs, water samples were collected continuously at the mouth of Sulphur Creek and in Dominion Creek just downstream of Sulphur Creek during the field studies in the Indian River watershed.

Due to size and level of mining activity, sampling in this watershed extended over a thirteen-day period. Logistically, the entire watershed could not be studied in one sampling period, and therefore the watershed was divided into four sub-drainages identified by Dominion Creek, Sulphur Creek, Eureka Creek and Quartz Creek. Maps detailing placer mining sites and water quality sampling results for the four sub-drainages are presented in Figures 4.10, 4.11, 4.12 and 4.13, respectively. These sub-drainages are discussed individually in the following sections.

In addition to these four sub-drainages, four study segments, have been specified to provide data required to calculate suspended sediment loadings. Although continuous records of NFR concentrations are available in Sulphur, Eureka and Quartz Creeks, suspended sediment loadings are not presented for these tributaries. Flow regulation by mine operators near the headwaters of these

creeks resulted in rapidly changing flow regimes. These unsteady flows were judged to be inappropriate for use in calculating suspended sediment loadings throughout these three creeks. Suspended sediment loadings from Sulphur, Eureka and Quartz Creeks are treated as point source inputs to these segments. Study segments begin near the headwaters of Dominion Creek and are sequential (A through D) downstream to the mouth of Indian River. These study segments are also presented in Figures 4.10, 4.11, 4.12 and 4.13. It must be noted that, due to limitations of available data, the periods of record for these study segments are not sequential.

4.5.1 Dominion Creek

Nine of sixteen identified active mines were visited in the Dominion Creek drainage. Three mines near the headwaters of Dominion Creek had completed sluicing for the season. The settling facilities in the next mine downstream, below Caribou Creek, consisted of long narrow ponds which drained by seepage through old dredge tailings. The effectiveness of this facility cannot be determined from the existing data as no point source discharge was identified. Settling facilities at two of the next four mines downstream on Dominion Creek appeared to be effective. The mine near the mouth of Portland Creek was totally recirculating process water. The mine upstream of Hunter Creek was using a large settling pond which appeared to be effective. The other two operations were discharging tailings water through old dredge tailings. Effectiveness of these facilities cannot be determined from the existing data. The settling facility at the mine downstream of Gold Run Creek, working on the ditch flowing parallel to Dominion Creek, was not effective. The final mine in this area discharged its effluent into old dredge tailings from where it seeped into Dominion Creek. The effectiveness of this facility cannot be determined from the existing data.

Suspended sediment concentrations in Dominion Creek below Sulphur Creek were observed to be relatively low, with only one peak having occurred. It is not clear whether this peak was in response to inputs from Sulphur Creek or Dominion Creek upstream.

4.5.2 Sulphur Creek

Seven of the thirteen identified active mines were visited in the Sulphur Creek drainage. Only two mines in the Sulphur Creek drainage had settling facilities that were effective. One mine totally recirculated its tailings water. The other mine, operating on Dominion Creek below Sulphur Creek, was using mined out pits for settling ponds which drained by seepage to Dominion Creek.

Near the headwaters of Sulphur Creek, the settling pond of the mine on Green Gulch was essentially full. The mine below Green Gulch had no settling facilities, and used the three pond system in the next mine downstream. This mine had completed operations prior to the site visit and had drained all three ponds. The effectiveness of settling facilities of the other two mines in this part of the drainage cannot be determined from the existing data.

Two active mines were present in the next reach downstream. The peak NFR concentration recorded at the bottom of this reach was the highest recorded by an automatic water sampler in the entire Indian River watershed.

Large NFR concentrations were also recorded approximately 2 km further downstream, but their magnitudes were reduced. These concentrations were observed to be further reduced near the mouth of Sulphur Creek. It is expected that these reductions resulted primarily from settling as very little tributary inflow was evident.

4.5.3 Eureka Creek

Three of the five active mines in the Eureka Creek drainage were visited during the field studies. Only two of these mines, both quite small, (located in the upper portion of the drainage) were actually operating. The large settling facility near the mouth of Eureka Creek appeared to be large enough to handle the suspended sediment loadings introduced by these two mines. However, a large quantity of suspended material was discharged from this pond in response to cyclical increases in suspended sediment loadings resulting from upstream mining operations.

4.5.4 Quartz Creek

Seven active mines were identified in the Quartz Creek drainage. Five of these mines were visited. Regulation of flow, through the use of the storage facilities developed by mines in the upper portion of the drainage, directly affected the flow regime and water quality throughout Quartz Creek. Very high suspended sediment concentrations were measured along the length of creek.

Extremely high suspended sediment concentrations were observed just downstream of the mine on Quartz Creek above Little Blanche Creek. Very little suspended sediment was evident in Little Blanche Creek during the site visits. Although Quartz Creek downstream of Little Blanche Creek passed through several old mine workings and its flow was increased by two non-industrial tributaries, suspended sediment concentrations remained very high near the mouth and contributed to the suspended sediment loading of the Indian River.

The only settling facilities in this drainage determined to be effective, were at two mines on Indian River just below Quartz Creek. Both mines recirculated

their process waters. No additional loadings to Indian River were evident. Water samples collected near the Yukon River confluence approximately 35 km downstream of the last mining site, contained low concentrations of suspended sediment.

In terms of the number of mining operations, the Indian River watershed was the largest of all watersheds studied. The effluent treatment facilities observed to be effective in this watershed used total recirculation or discharged by seepage, either through settling pond berms or old mine tailings.

Very high concentrations of suspended sediment were observed at various locations throughout the Indian River drainage. The high concentrations of suspended sediment recorded in the upper portions of the watershed (Gold Run Creek and Sulphur Creek) reduced rapidly as these waters passed through settling facilities at downstream mines. However in the smaller and less active portions of the drainage (Quartz Creek for example) levels of suspended sediment appeared to persist and contributed proportionately larger amounts of suspended sediments to Indian River.

4.6 South Big Salmon River

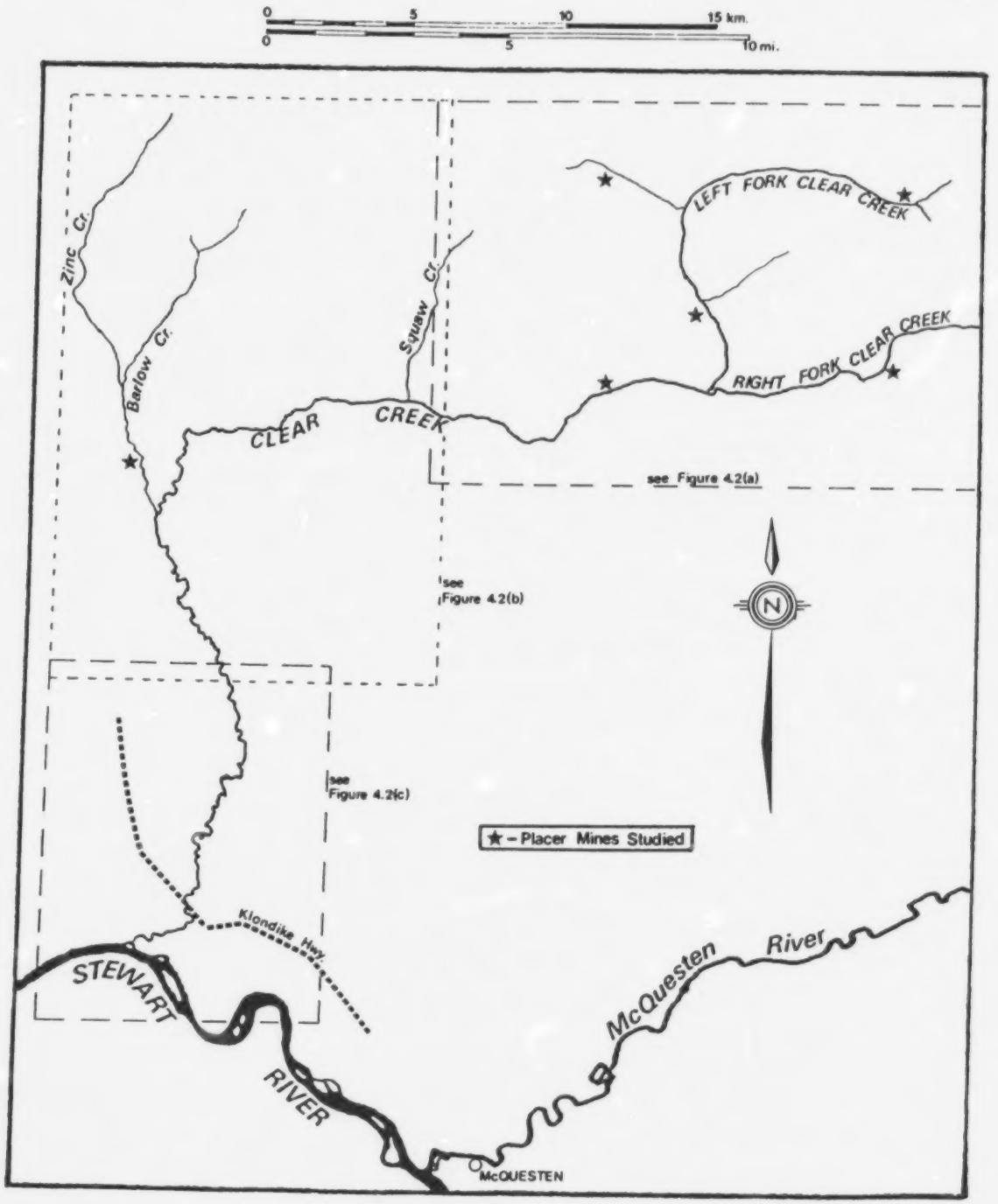
Three of the ten active mines identified in the South Big Salmon River watershed (Figures 4.14 and 4.15) were visited. Only two of the three mines were operating during the site visit. Efficiencies of settling facilities at these mines are unknown. The South Big Salmon River watershed consists of numerous non-industrial and industrial tributaries throughout its drainage. Water samples collected from industrial tributaries on which active mines were not operating or non-industrial tributaries contained very small concentrations of suspended sediment.

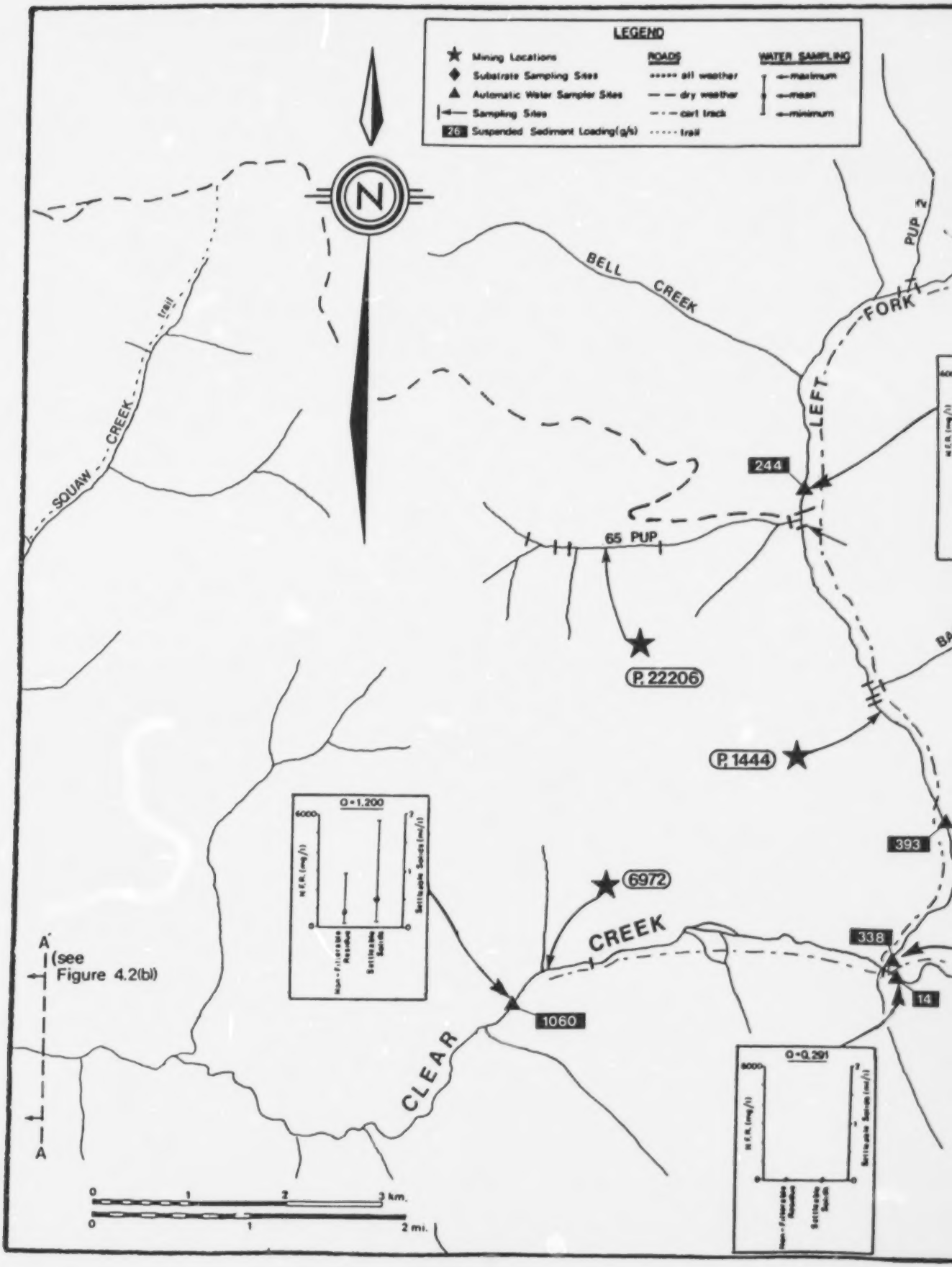
Concentrations of NFR recorded throughout most of South Big Salmon River were observed to be low. Concentrations of suspended material input from industrial tributaries were diluted by the much larger flow in South Big Salmon River.

Suspended sediment levels recorded in Livingstone Creek were observed to be lower than in South Big Salmon River upstream of Livingstone Creek. The combined flow of Cottoneva Creek and Lake Creek (industrial tributaries) provided large amounts of suspended sediment to South Big Salmon River. Water samples collected downstream of Lake Creek showed a small increase in NFR concentrations probably in response to the mining activities on Little Violet Creek and Lake Creek.

Calculated suspended sediment loadings in South Big Salmon River increased noticeably from above Martin Creek to just upstream of Mendocina Creek. The suspended sediment loading in Mendocina Creek was comparatively low. Non-industrial inflows that were sampled were contributing a significant proportion of the sediment loading to the South Big Salmon River. Water quality of samples collected in South Big Salmon River near the mouth was observed to be very similar to Big Salmon River downstream.

FIGURE 4.1 : CLEAR CREEK




LEGEND
Mining Locations
Substrate Sampling Sites
Automatic Water Sampler Sites
Sampling Sites
26 Suspended Sediment Loading(g/s)
ROADS
all weather
dry weather
cart track
trail
WATER SAMPLING
maximum
mean
minimum
N
BELL CREEK
PUP 2
FORK
LEFT
SQUAW CREEK
trail
244
65 PUP
P.22206
P.1444
393
6972
CREEK
338
14
1060
CLEAR
A
(see Figure 4.2(b))
A
Q=1.200
Q=0.291
0 1 2 3 km.
0 1 2 mi.

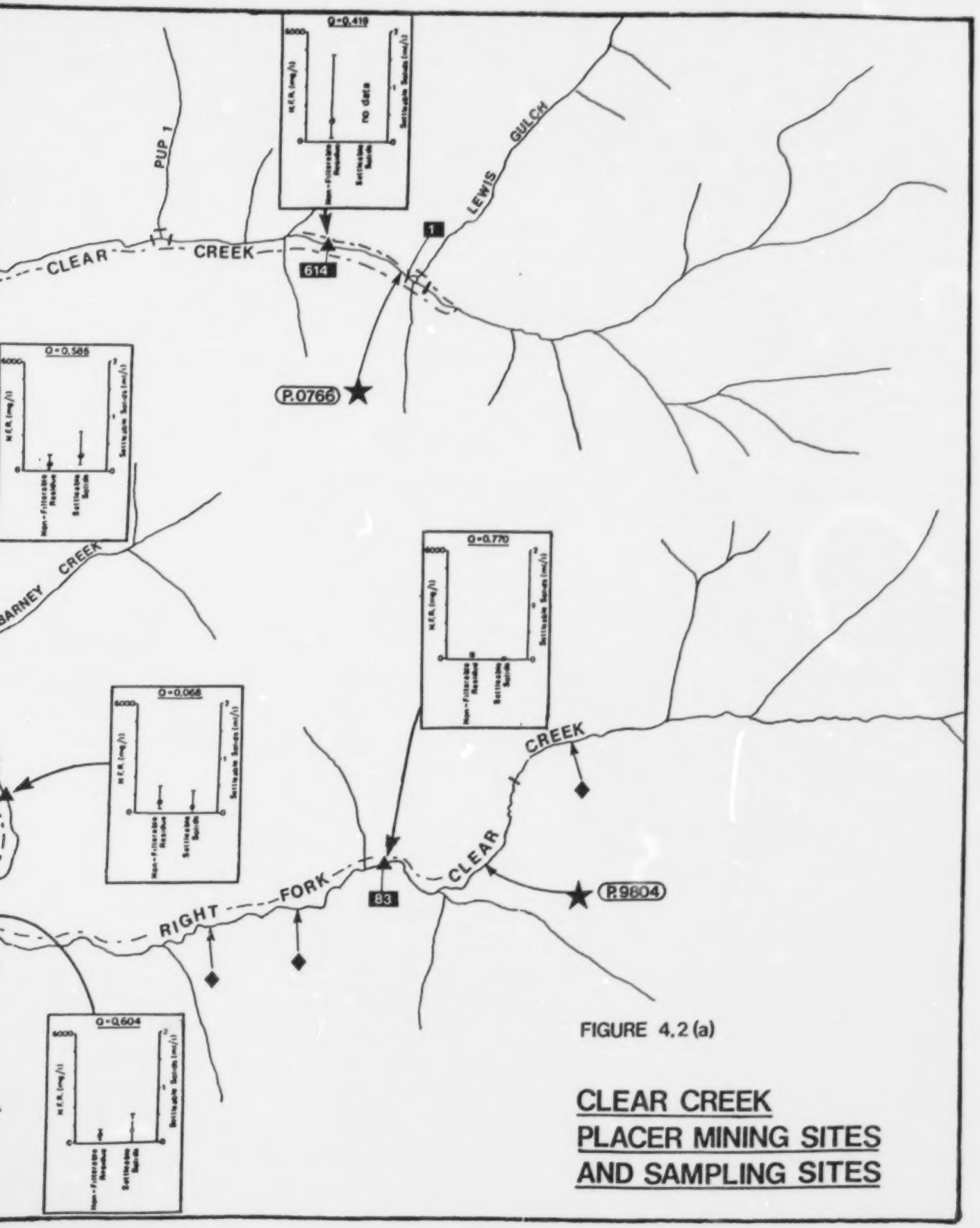
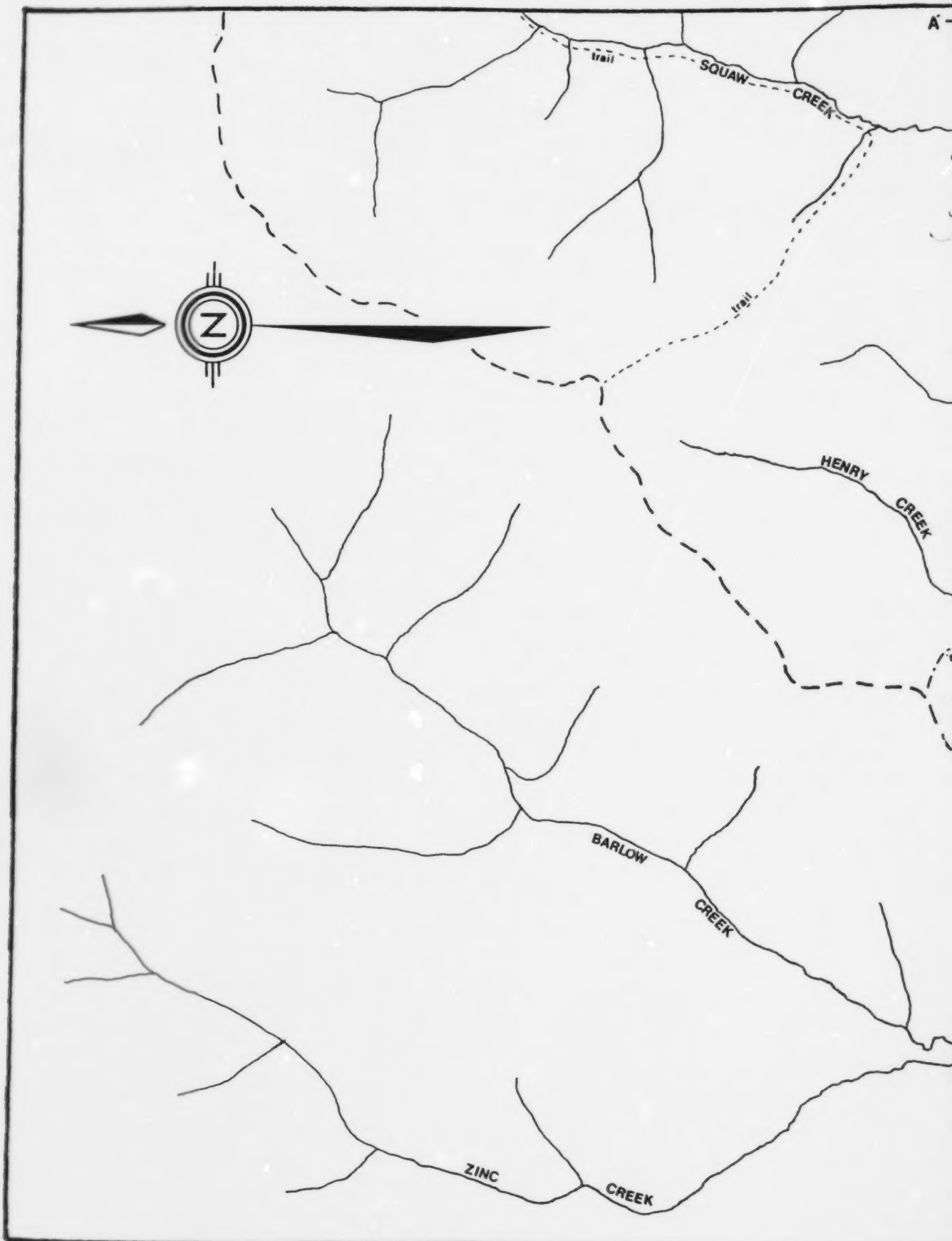
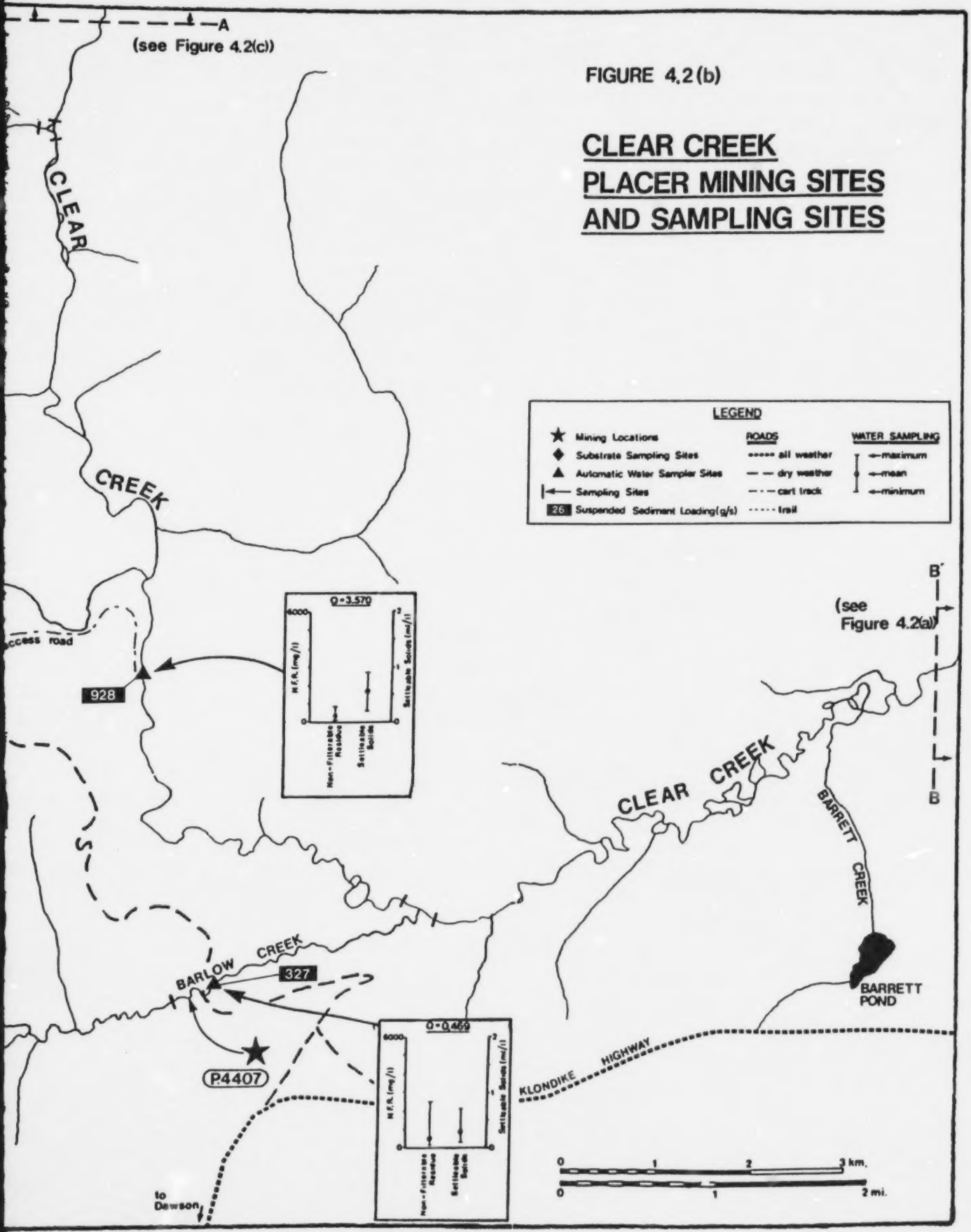


FIGURE 4.2 (a)

CLEAR CREEK PLACER MINING SITES AND SAMPLING SITES


A
trail
SQUAW
CREEK
trail
HENRY
CREEK
BARLOW
CREEK
ZINC
CREEK


A
(see Figure 4.2(c))
FIGURE 4.2 (b)
CLEAR CREEK
PLACER MINING SITES
AND SAMPLING SITES
CLEAR
CREEK
LEGEND
Mining Locations
Substrate Sampling Sites
Automatic Water Sampler Sites
Sampling Sites
26 Suspended Sediment Loading(g/s)
ROADS
all weather
dry weather
cart track
trail
WATER SAMPLING
maximum
mean
minimum
B'
(see Figure 4.2(a))
B
Q-3.570
4000
N.F.R.(mg/l)
Settleable Solids (ml/l)
Non-Filterable Residue
Settleable Solids
ccess road
928
CLEAR CREEK
BARRETT CREEK
BARLOW CREEK
327
BARRETT POND
Q-0.469
P4407
KLONDIKE HIGHWAY
to Dawson
0 1 2 3 km.
0 1 2 mi.

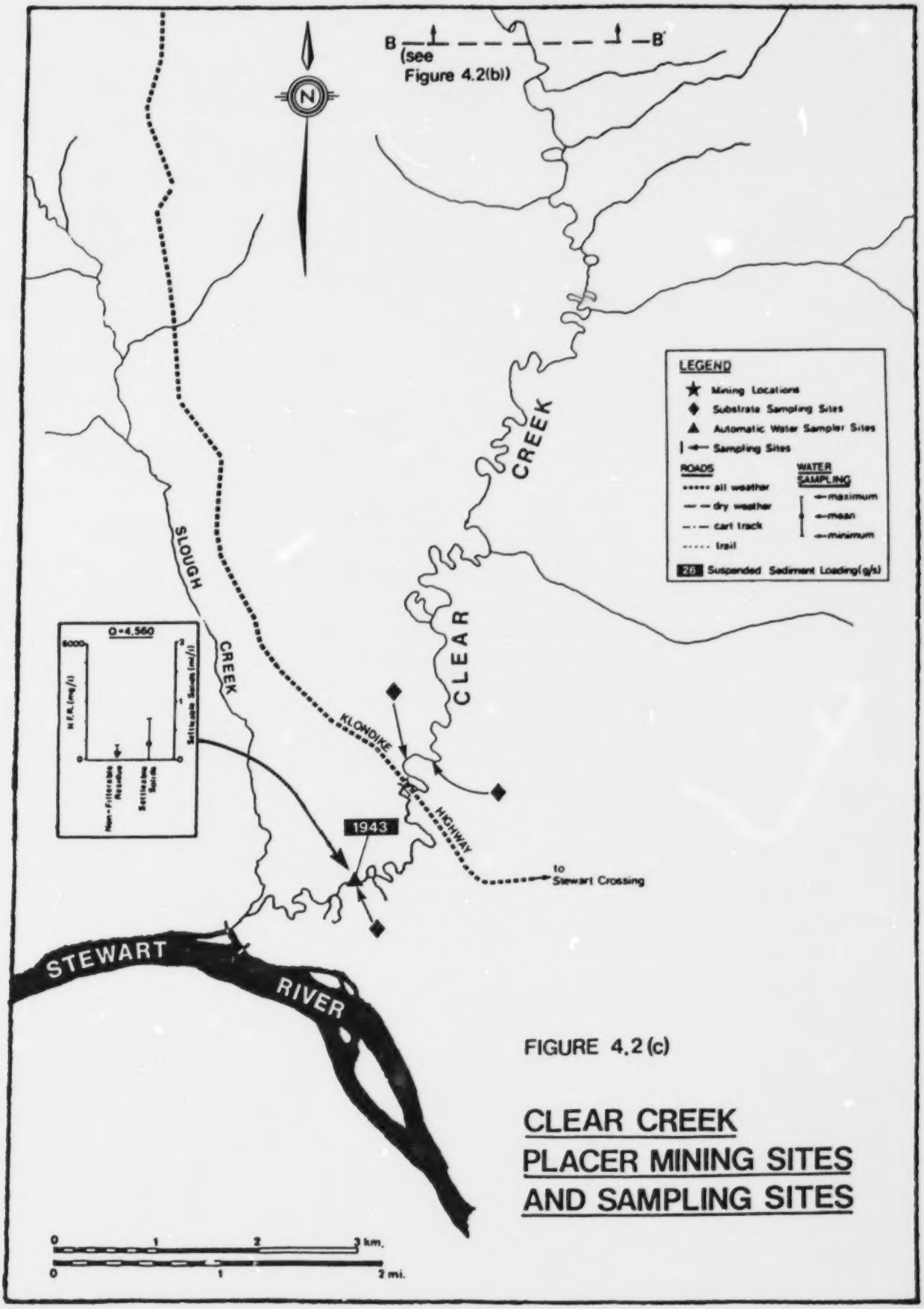
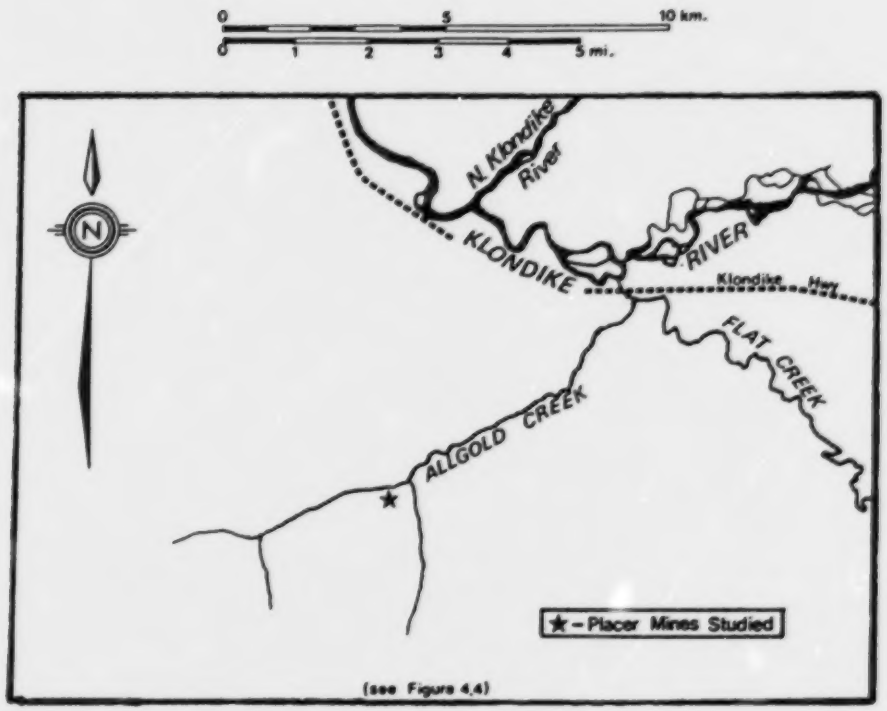
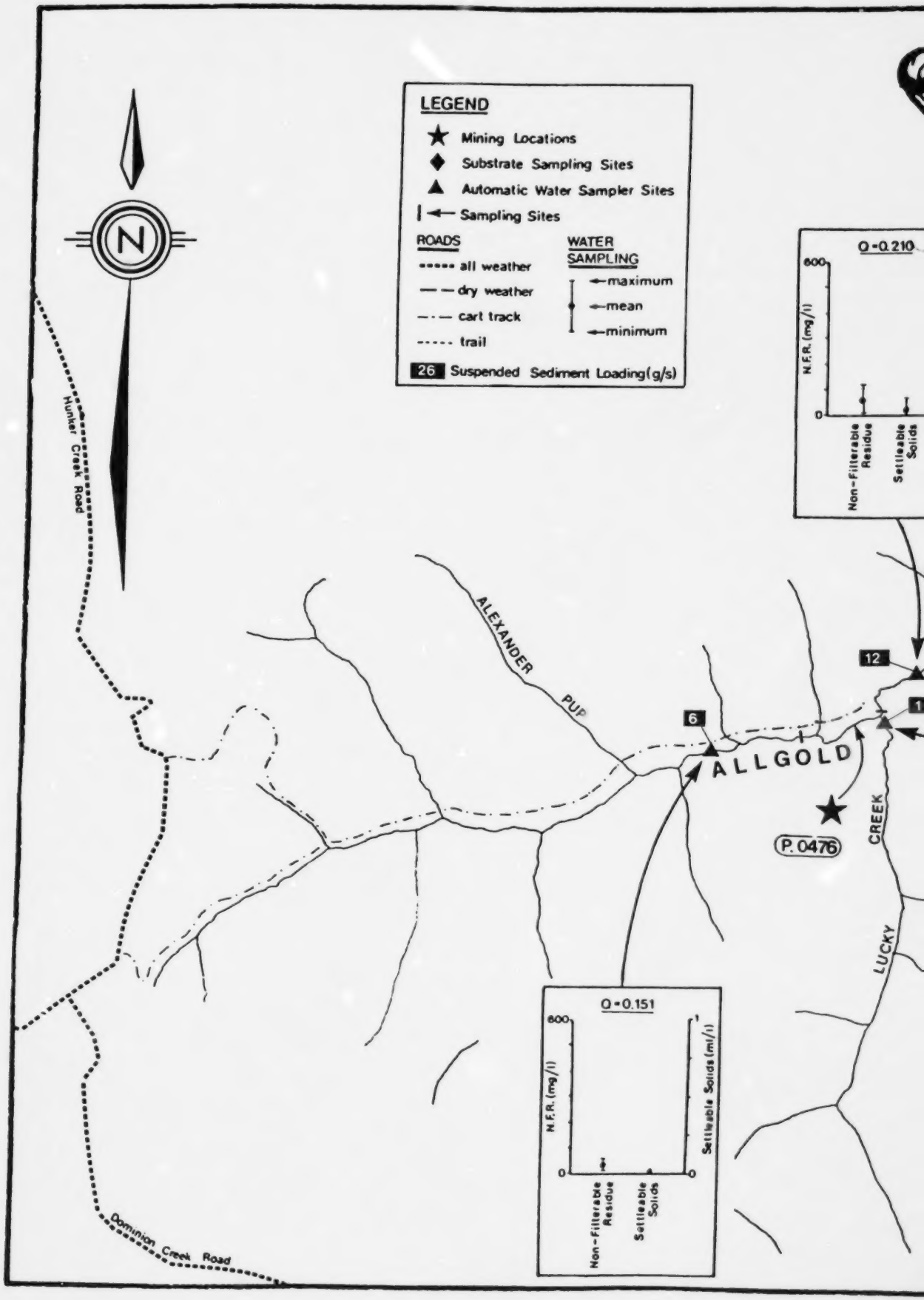


FIGURE 4.2 (c)

CLEAR CREEK PLACER MINING SITES AND SAMPLING SITES

FIGURE 4.3 : ALLGOLD CREEK




LEGEND
Mining Locations
Substrate Sampling Sites
Automatic Water Sampler Sites
Sampling Sites
ROADS
all weather
dry weather
cart track
trail
WATER SAMPLING
maximum
mean
minimum
26 Suspended Sediment Loading(g/s)
N
Hunker Creek Road
Dominion Creek Road
ALEXANDER PUP
ALLGOLD
CREEK
LUCKY
P.0476
6
12
1
Q=0.210
600
0
N.F.R. (mg/l)
Non-Filterable Residue
Settleable Solids
Q=0.151
600
0
N.F.R. (mg/l)
Settleable Solids (ml/l)
1
0
Non-Filterable Residue
Settleable Solids

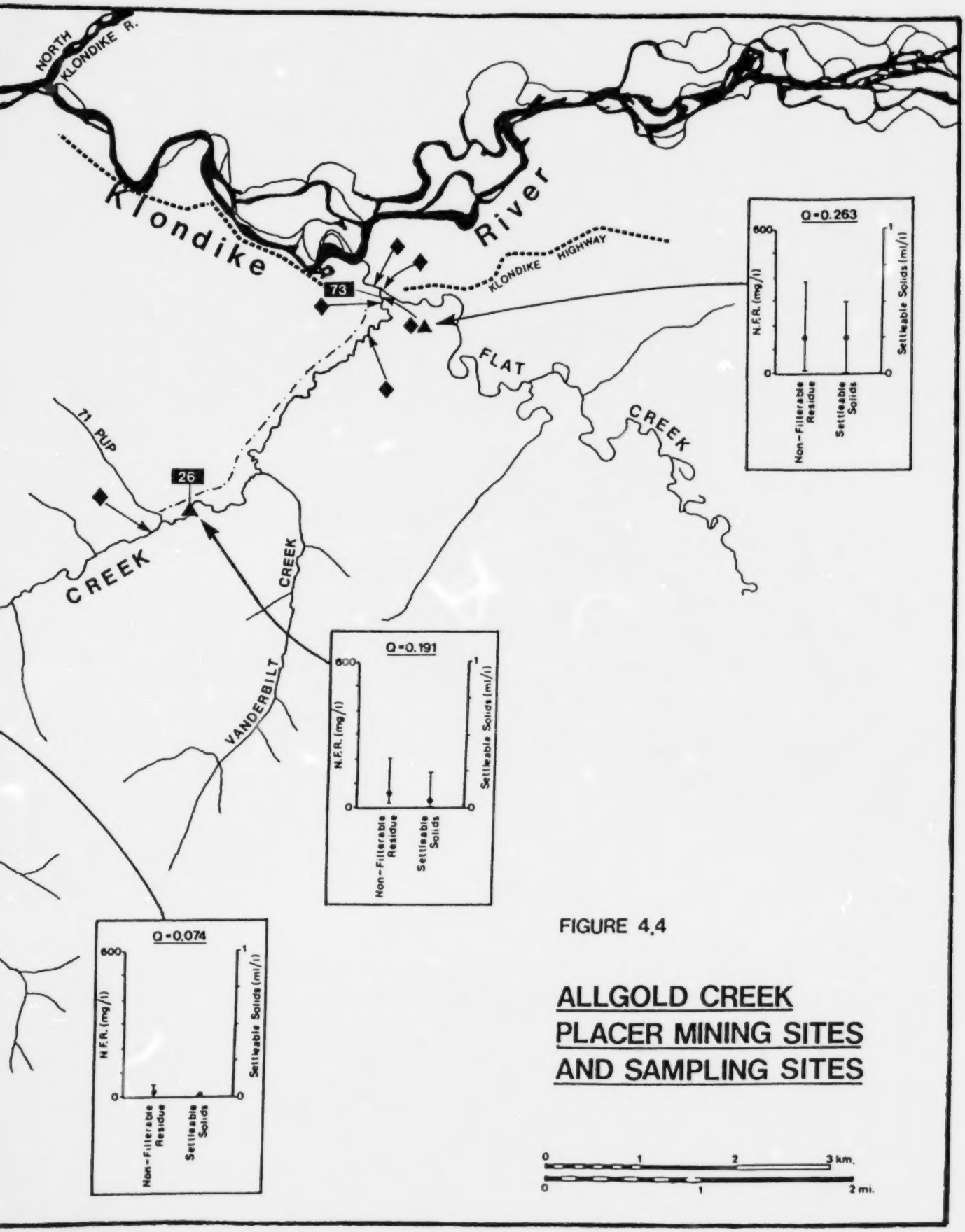


FIGURE 4.4

ALLGOLD CREEK PLACER MINING SITES AND SAMPLING SITES

FIGURE 4.5 : **HAGGART CREEK**

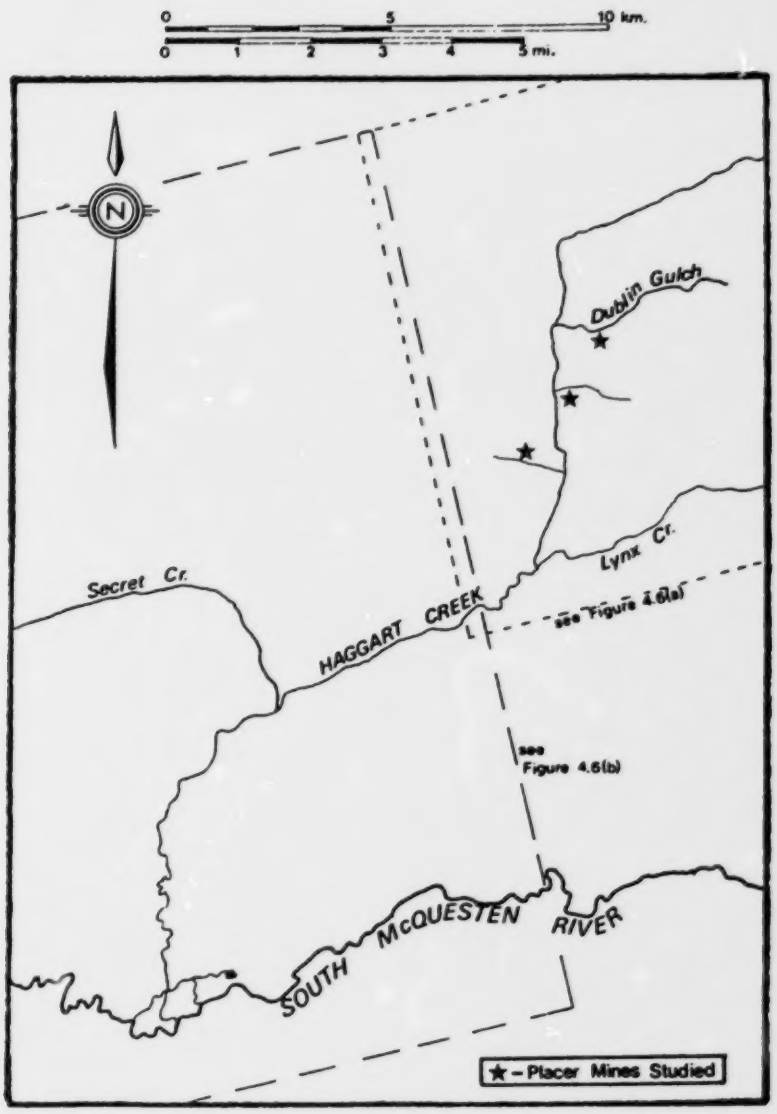


FIGURE 4.6(a)

HAGGART CREEK PLACER MINING SITES AND SAMPLING SITES

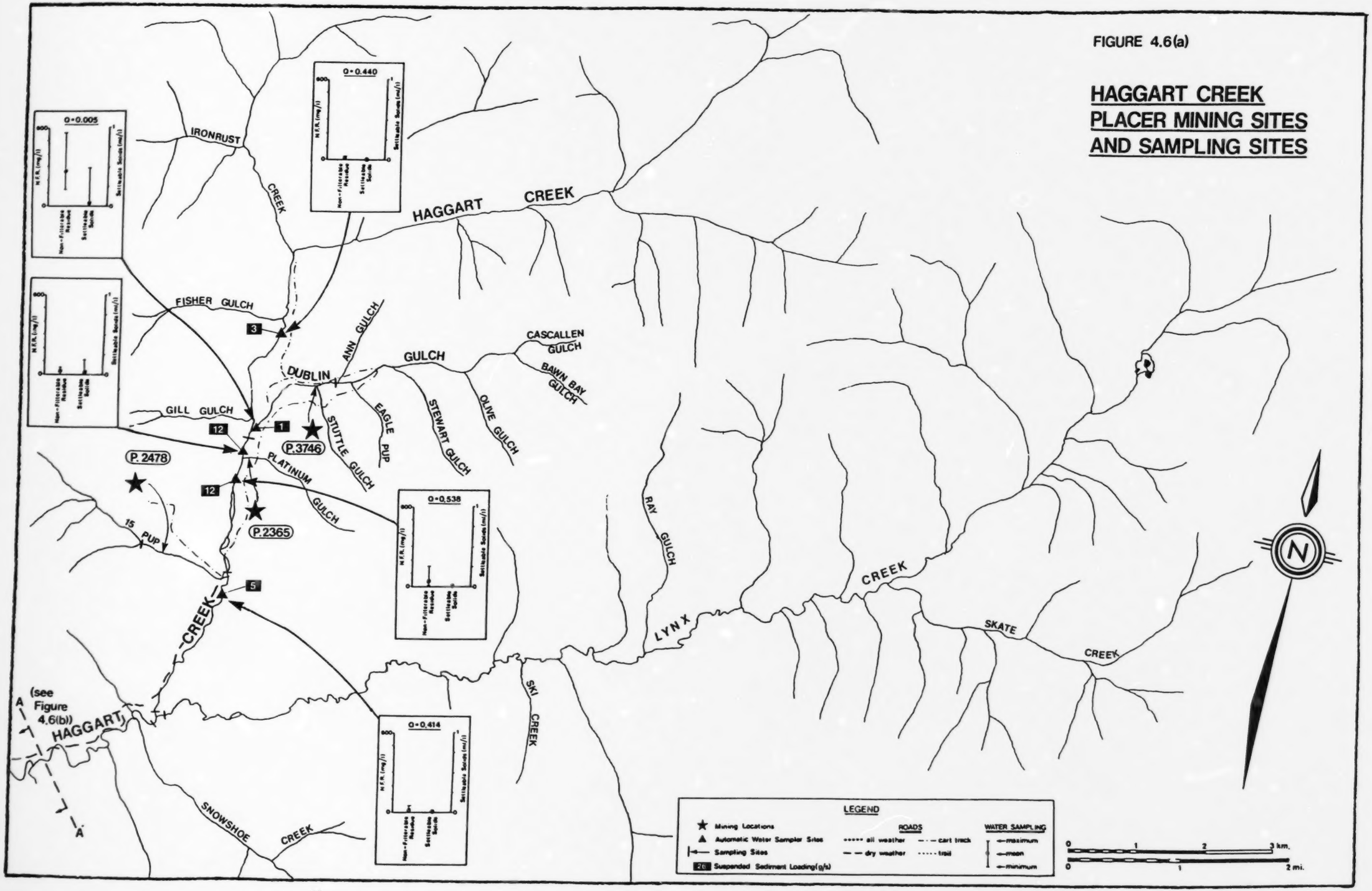


FIGURE 4.6(b)

HAGGART CREEK PLACER MINING SITES AND SAMPLING SITES

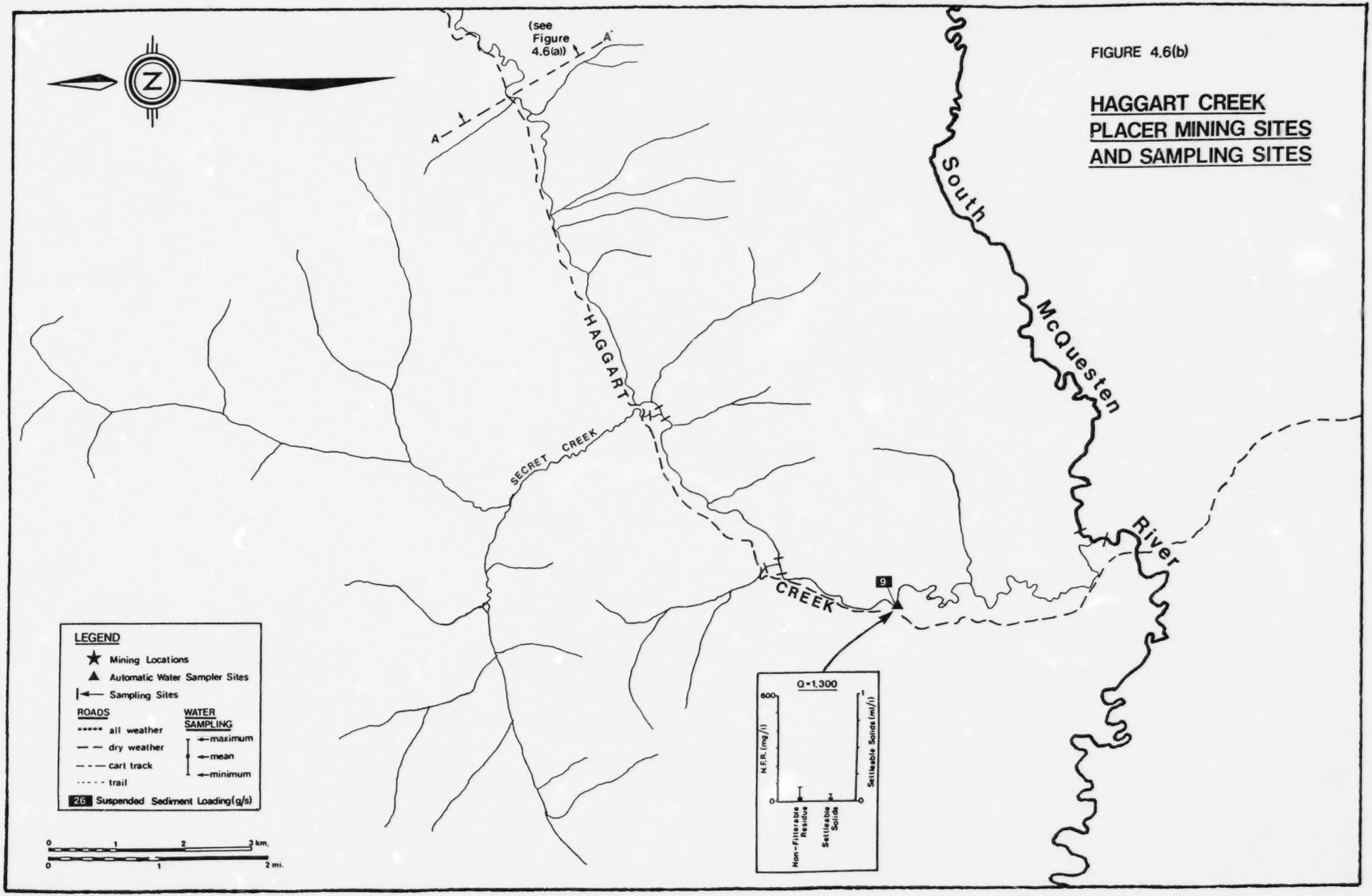
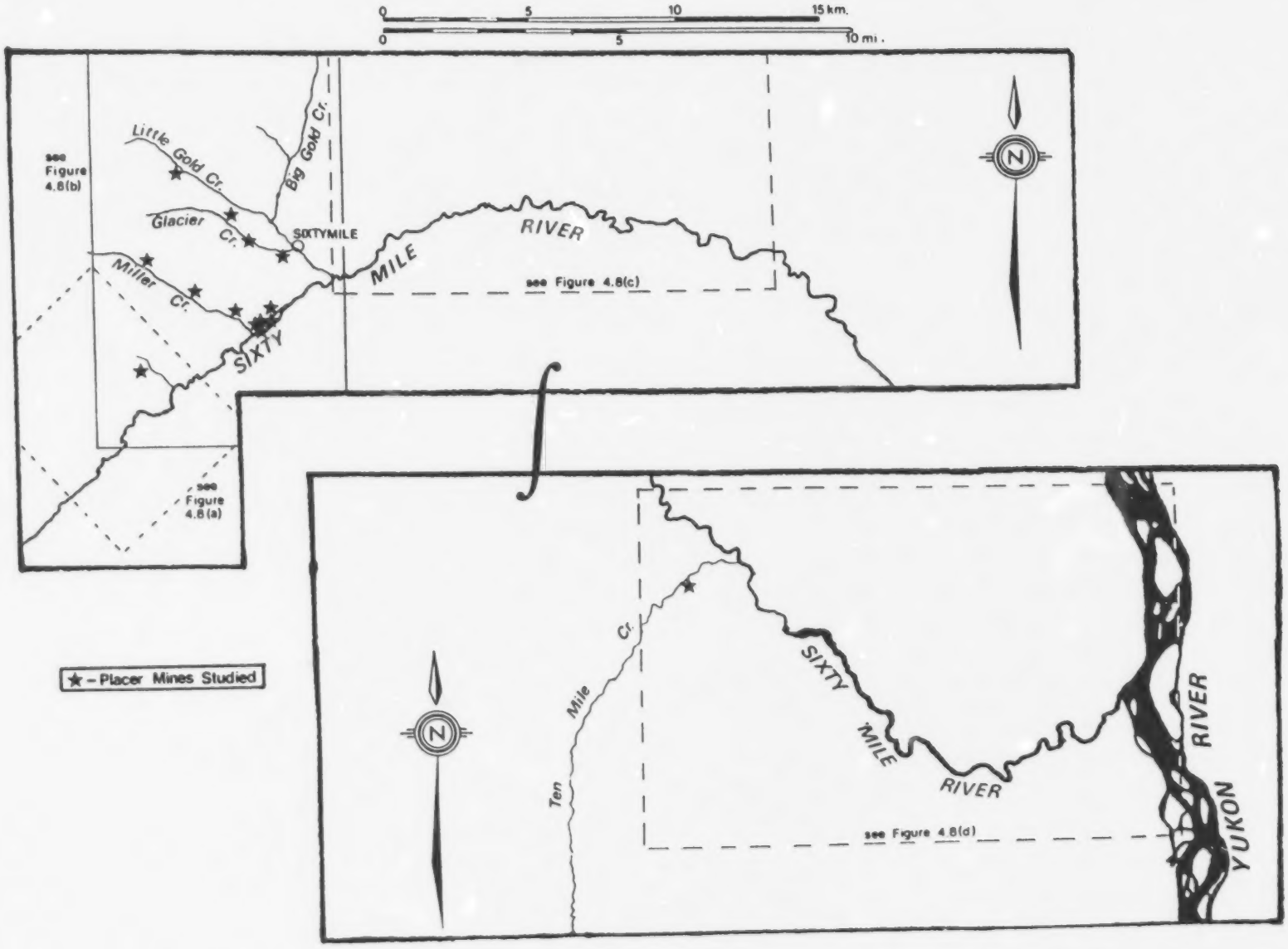


FIGURE 4.7 : **SIXTY MILE RIVER**



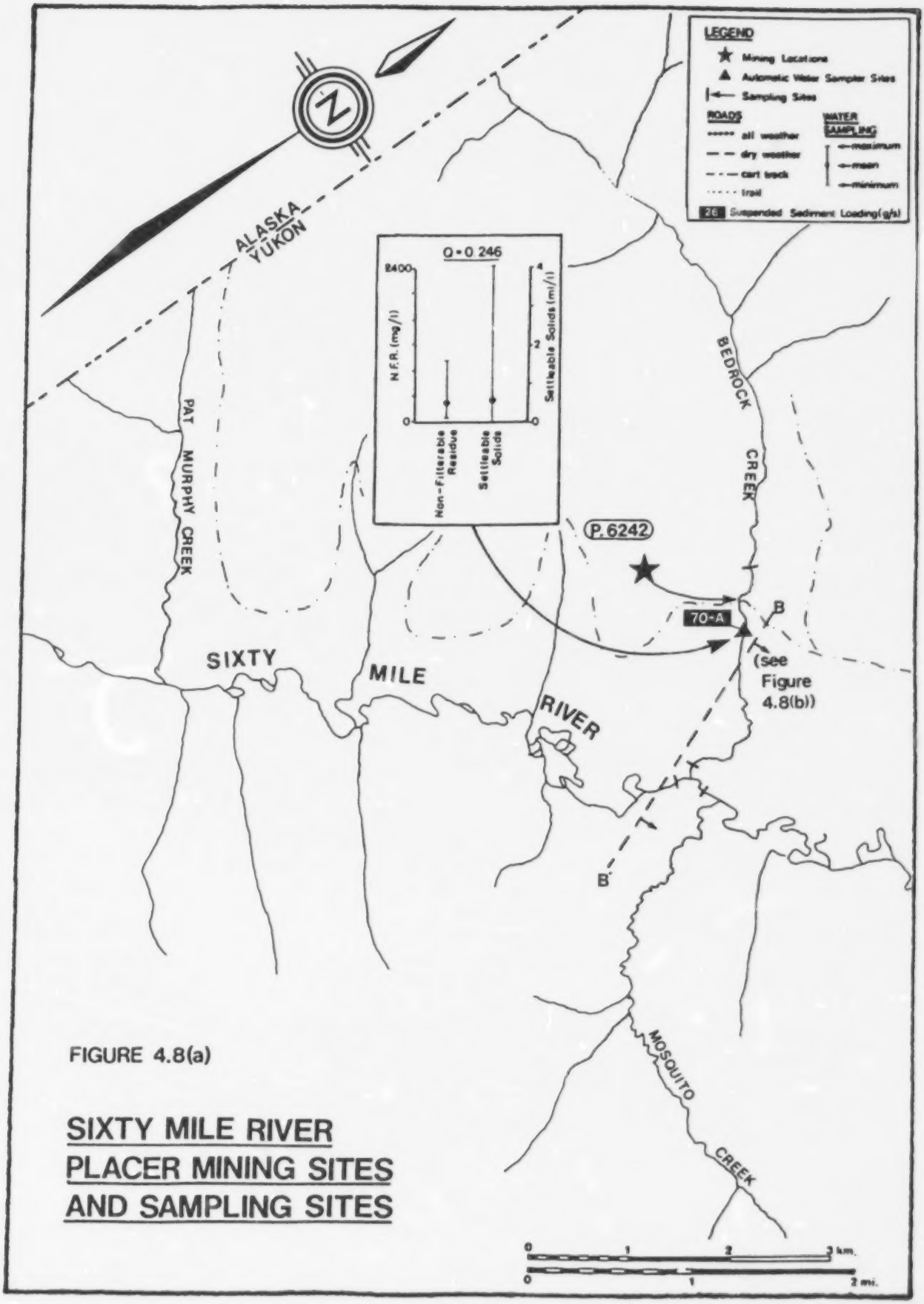


FIGURE 4.8(a)

SIXTY MILE RIVER PLACER MINING SITES AND SAMPLING SITES

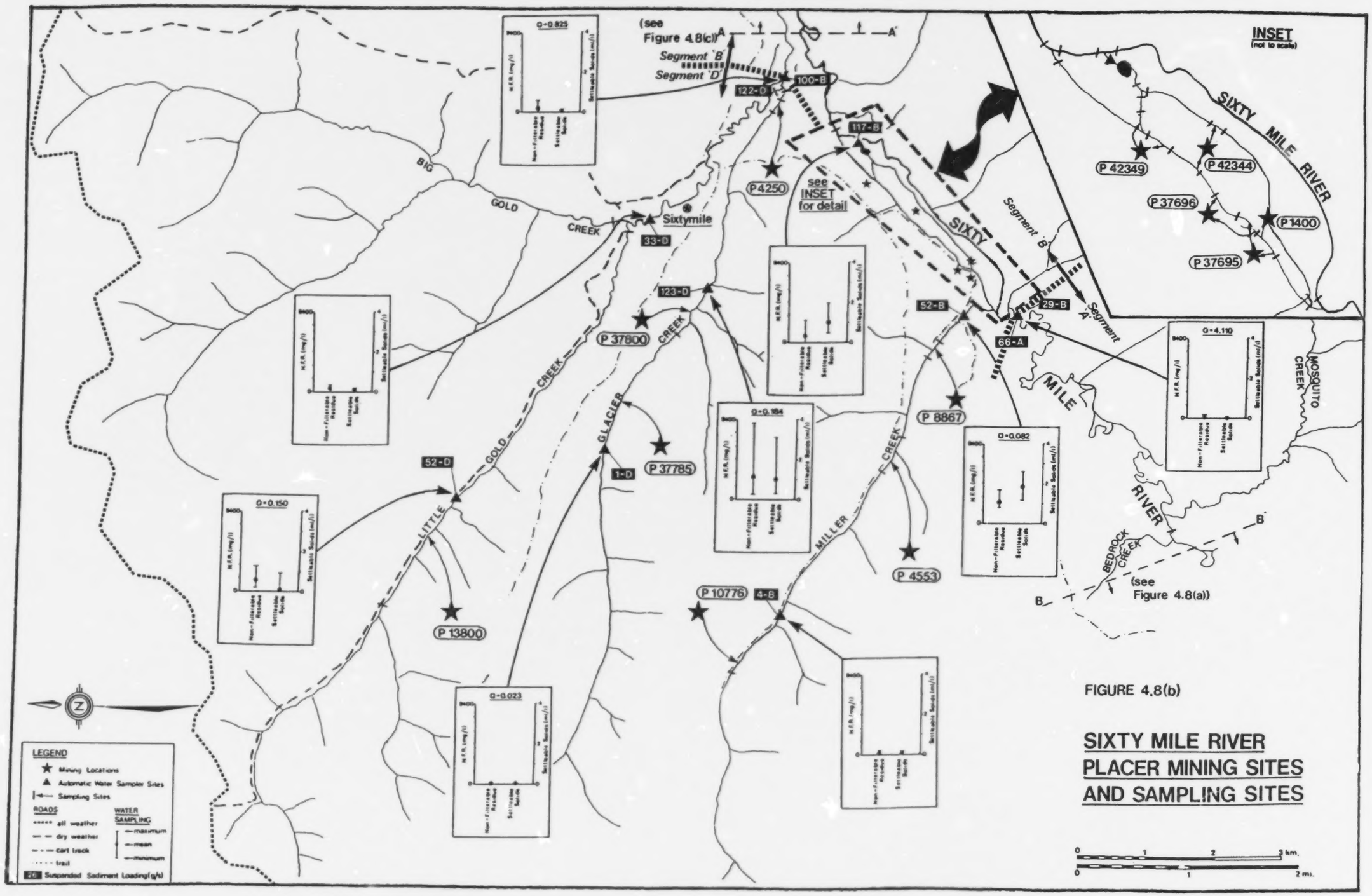


FIGURE 4.8(b)

SIXTY MILE RIVER PLACER MINING SITES AND SAMPLING SITES

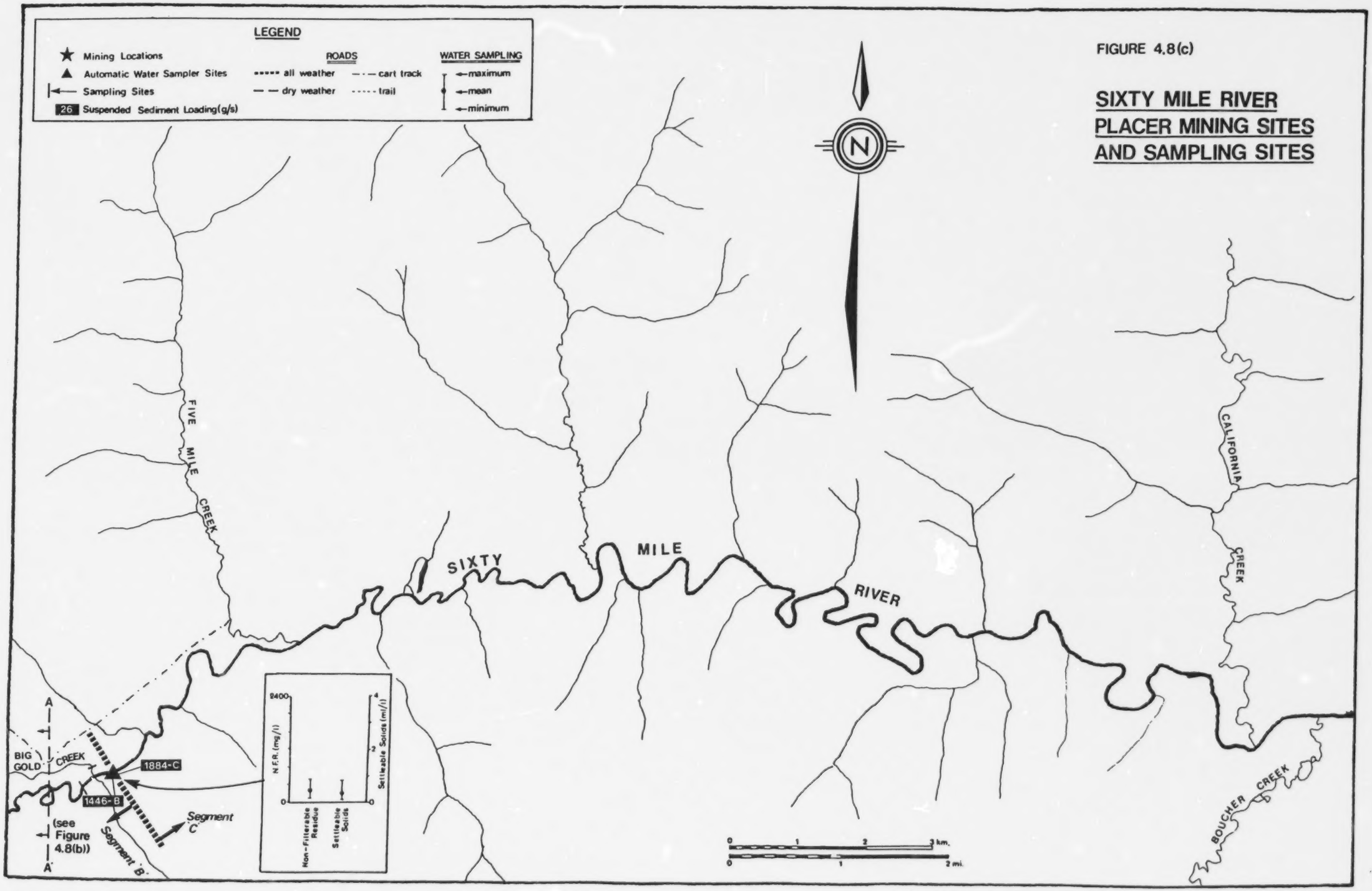


FIGURE 4.8(c)

SIXTY MILE RIVER PLACER MINING SITES AND SAMPLING SITES

FIGURE 4.8(d)

SIXTY MILE RIVER PLACER MINING SITES AND SAMPLING SITES

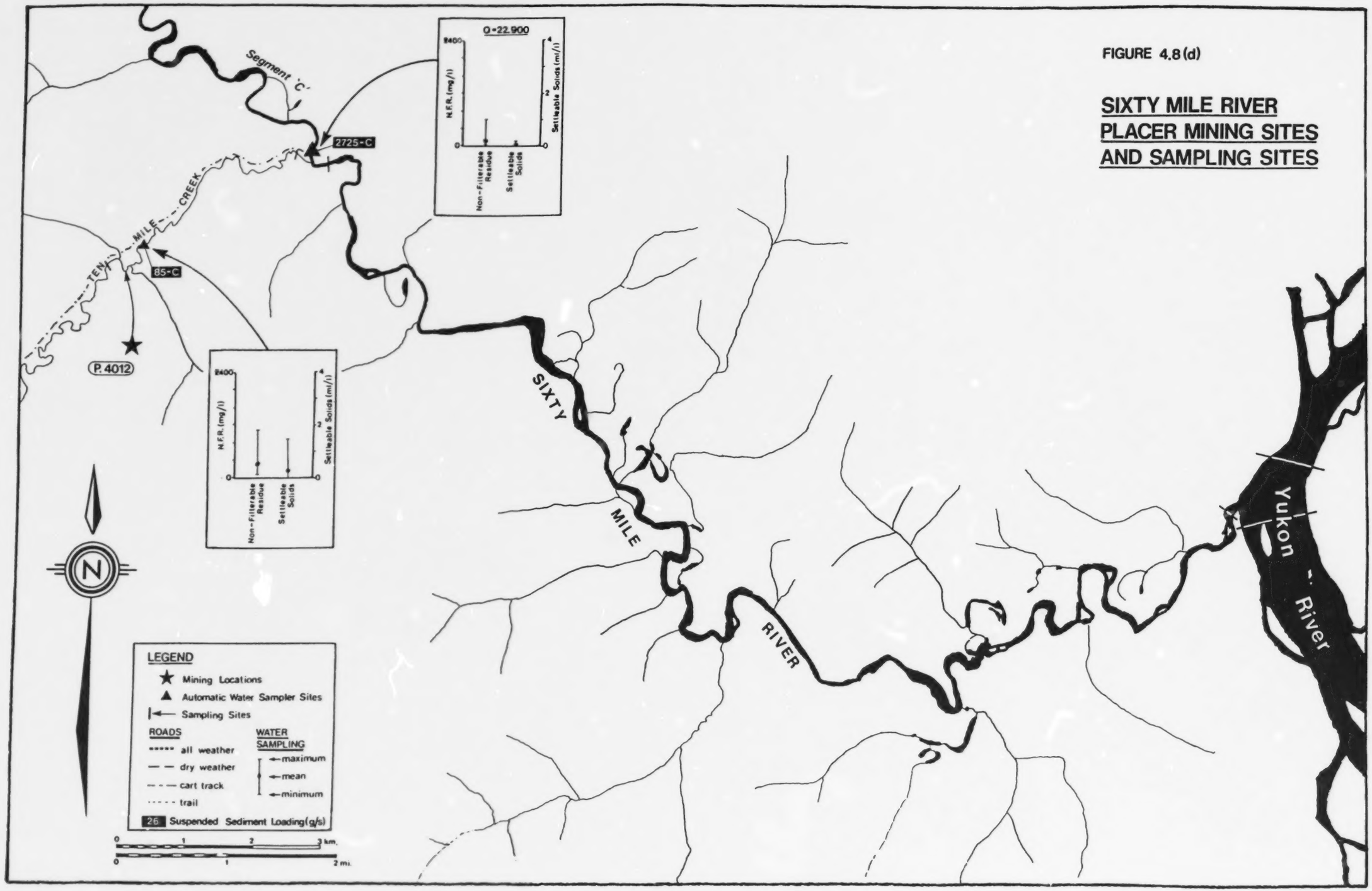
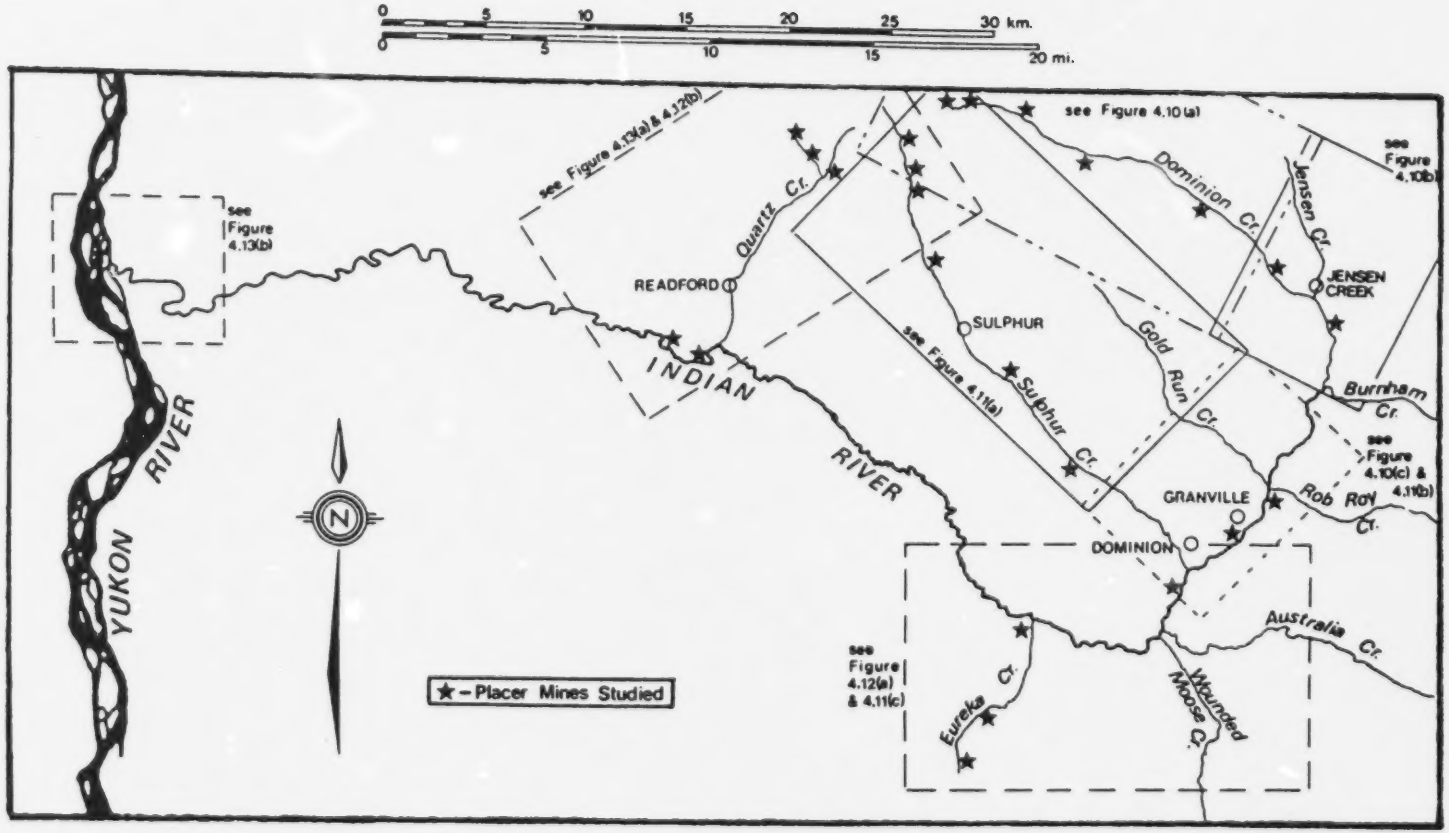


FIGURE 4.9 : **INDIAN RIVER**



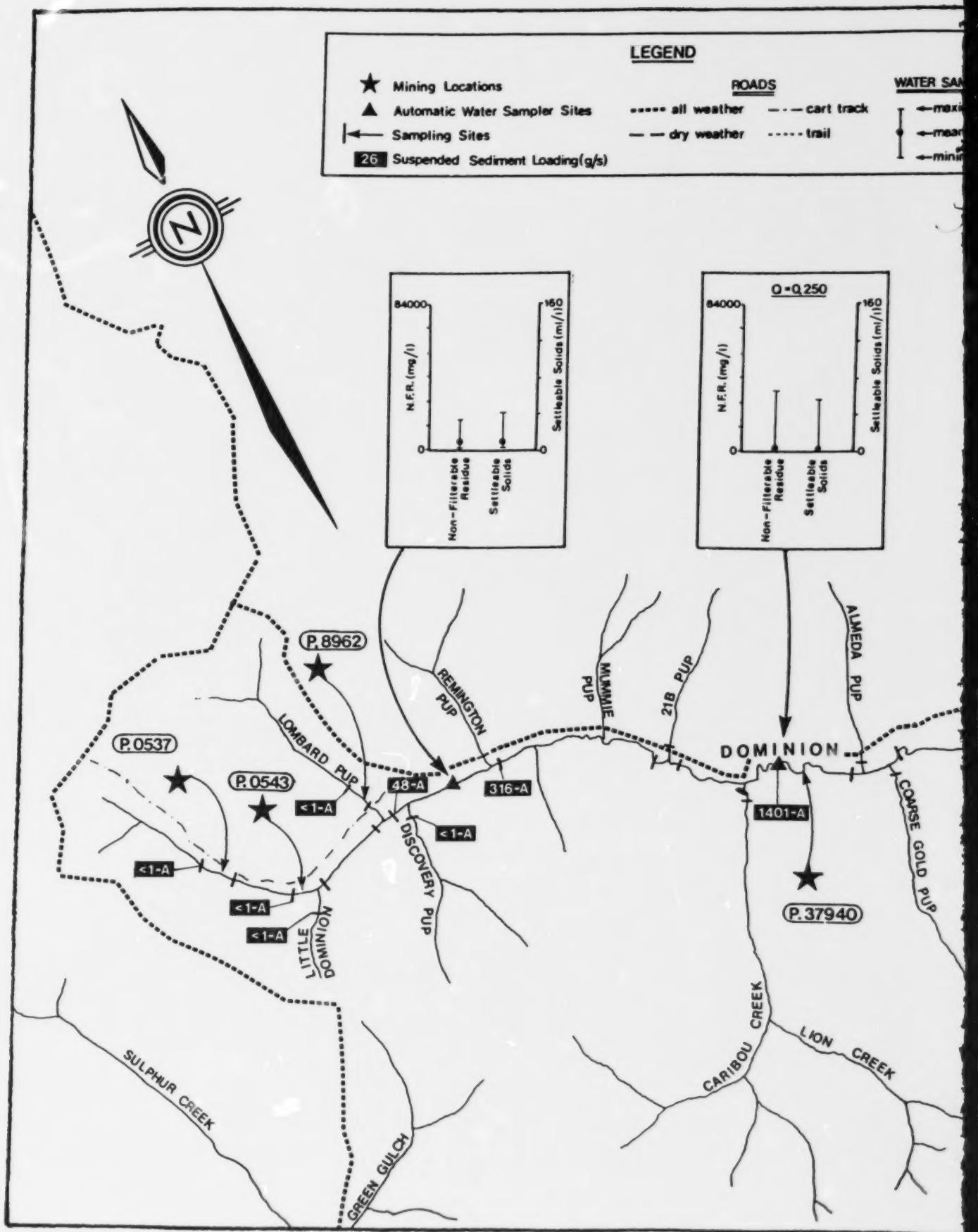

LEGEND
Mining Locations
Automatic Water Sampler Sites
Sampling Sites
26 Suspended Sediment Loading(g/s)
ROADS
all weather
dry weather
cart track
trail
WATER SA
N
84000
0
N.F.R. (mg/l)
160
0
Settleable Solids (ml/l)
Non-Filterable Residue
Settleable Solids
Q = Q 250
P.8962
P.0537
P.0543
P.37940
LOMBARD PUP
REMINGTON PUP
MUMMIE PUP
218 PUP
ALMEDA PUP
DOMINION
COARSE GOLD PUP
DISCOVERY PUP
LITTLE DOMINION
SULPHUR CREEK
GREEN GULCH
CARIBOU CREEK
LION CREEK
48-A
316-A
1401-A
<1-A

FIGURE 4.10(a)

DOMINION CREEK PLACER MINING SITES AND SAMPLING SITES

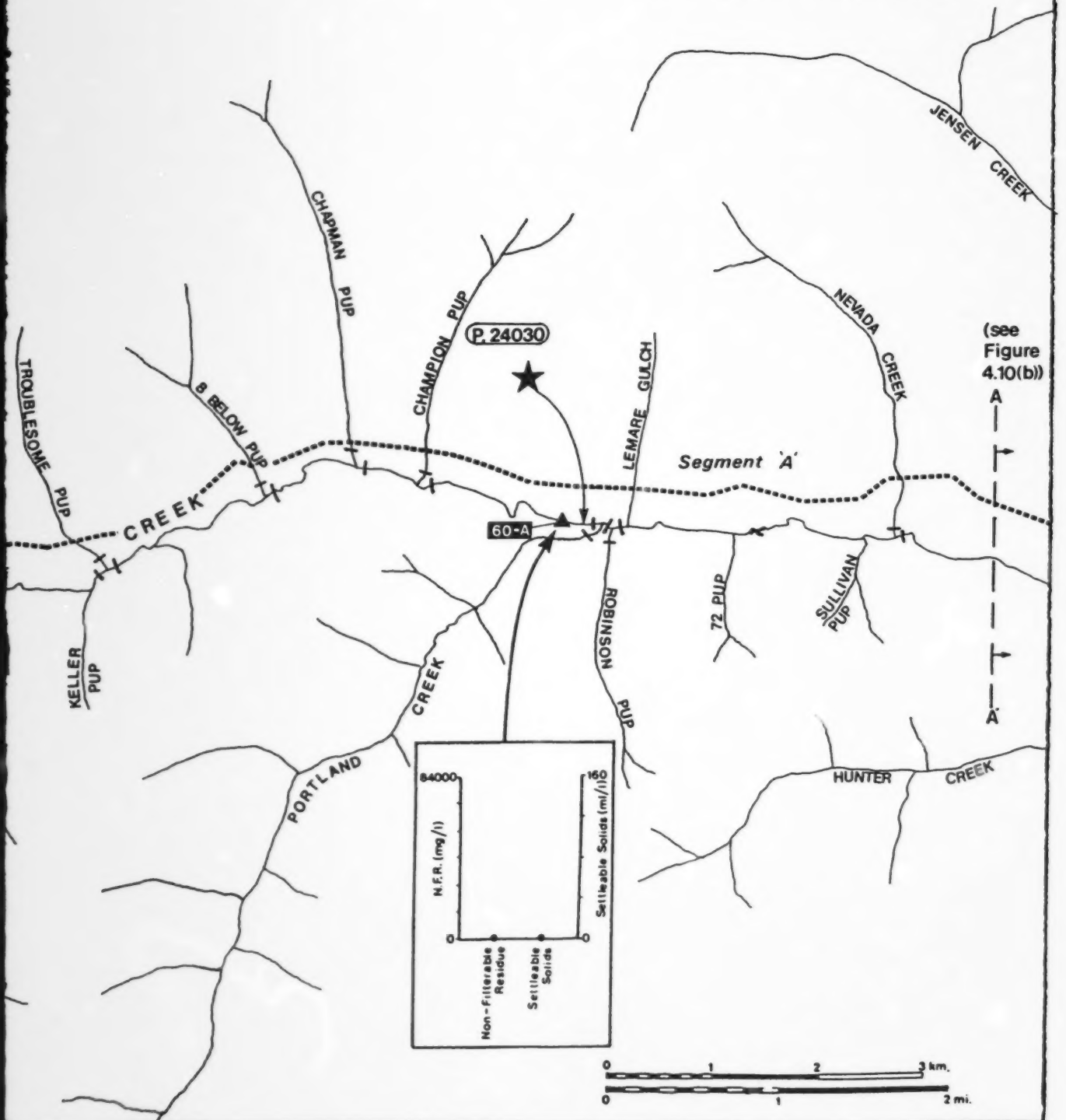
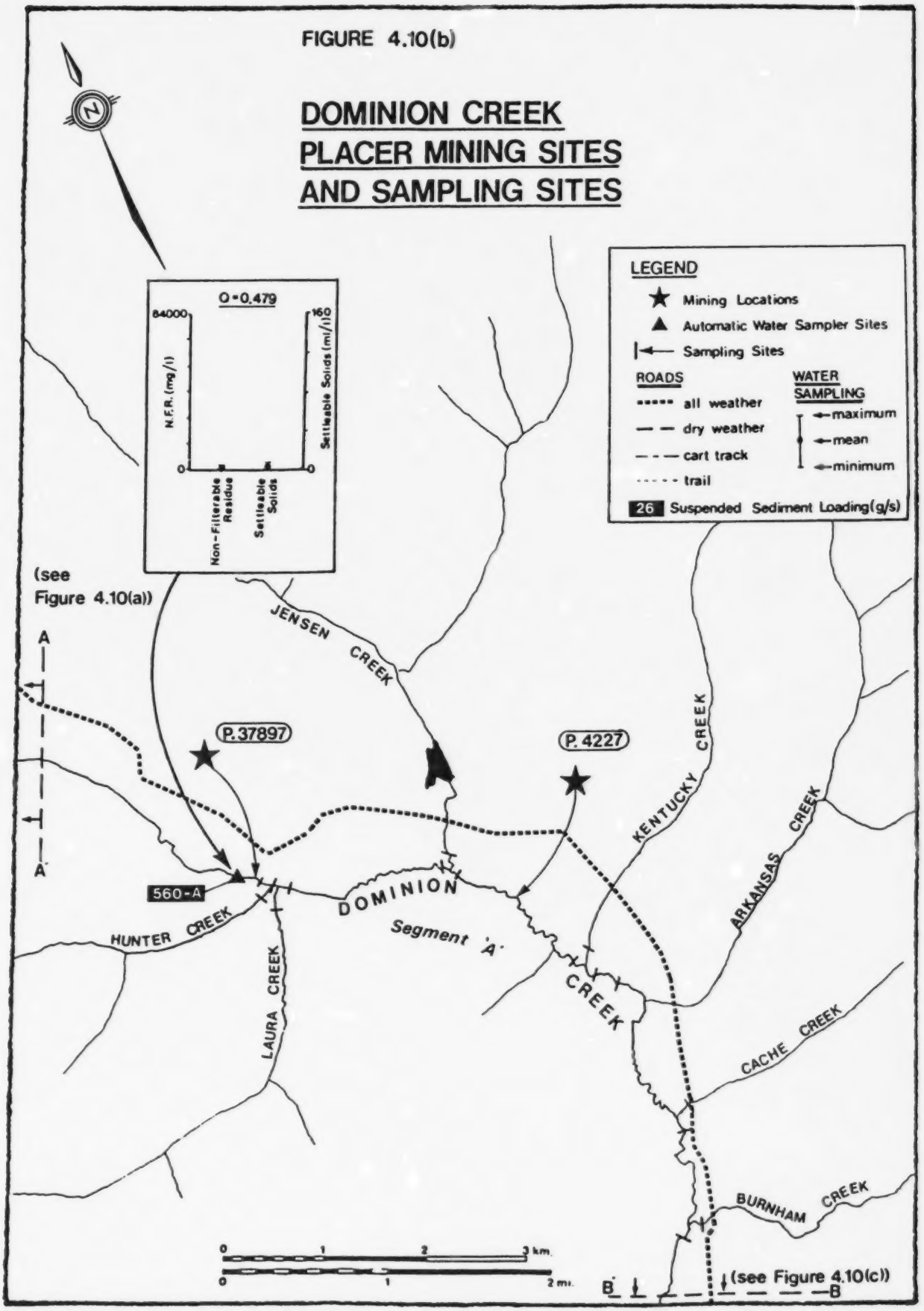


FIGURE 4.10(b)


DOMINION CREEK
PLACER MINING SITES
AND SAMPLING SITES
N
LEGEND
Mining Locations
Automatic Water Sampler Sites
Sampling Sites
ROADS
all weather
dry weather
cart track
trail
WATER SAMPLING
maximum
mean
minimum
26 Suspended Sediment Loading(g/s)
O = 0.479
84000
N.F.R. (mg/l)
0
160
Settleable Solids (ml/l)
0
Non-Filterable Residue
Settleable Solids
(see Figure 4.10(a))
A
A'
JENSEN CREEK
P.37897
P.4227
KENTUCKY CREEK
ARKANSAS CREEK
560-A
DOMINION
Segment 'A'
HUNTER CREEK
LAURA CREEK
CREEK
CACHE CREEK
BURNHAM CREEK
0 1 2 3 km.
0 1 2 mi.
B'
B
(see Figure 4.10(c))

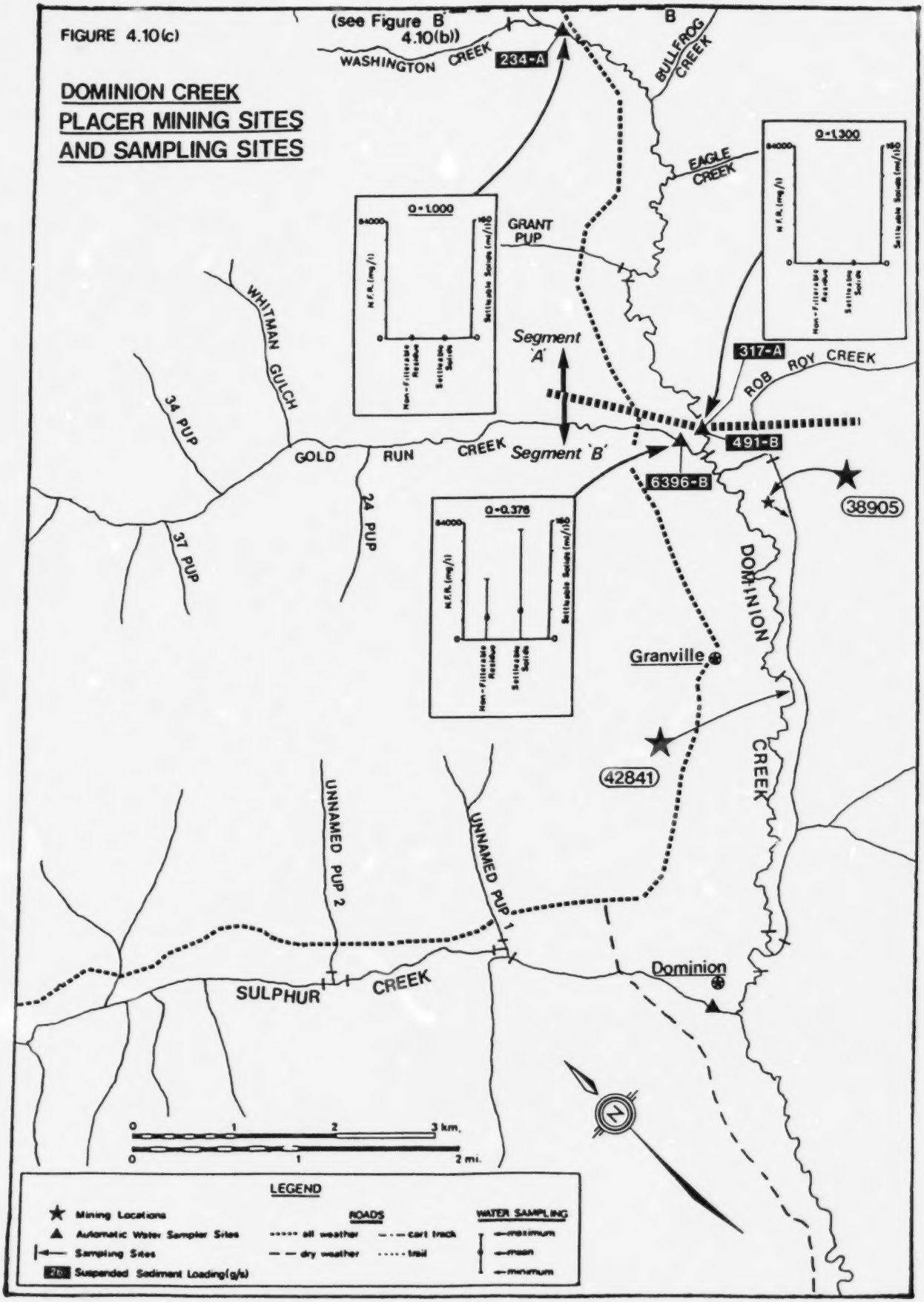


FIGURE 4.10(c)
DOMINION CREEK
PLACER MINING SITES
AND SAMPLING SITES
(see Figure B 4.10(b))
B
WASHINGTON CREEK
234-A
BULLFROG CREEK
EAGLE CREEK
0-1300
0-1000
GRANT PUP
WHITMAN GULCH
Segment 'A'
317-A
ROB ROY CREEK
34 PUP
GOLD RUN CREEK
Segment 'B'
491-B
6396-B
38905
24 PUP
37 PUP
0-0.378
DOMINION CREEK
Granville
42841
UNNAMED PUP 2
UNNAMED PUP 1
Dominion
SULPHUR CREEK
0 1 2 3 km.
0 1 2 mi.
LEGEND
Mining Locations
Automatic Water Sampler Sites
Sampling Sites
Suspended Sediment Loading(g/s)
ROADS
all weather
dry weather
cart track
trail
WATER SAMPLING
maximum
mean
minimum

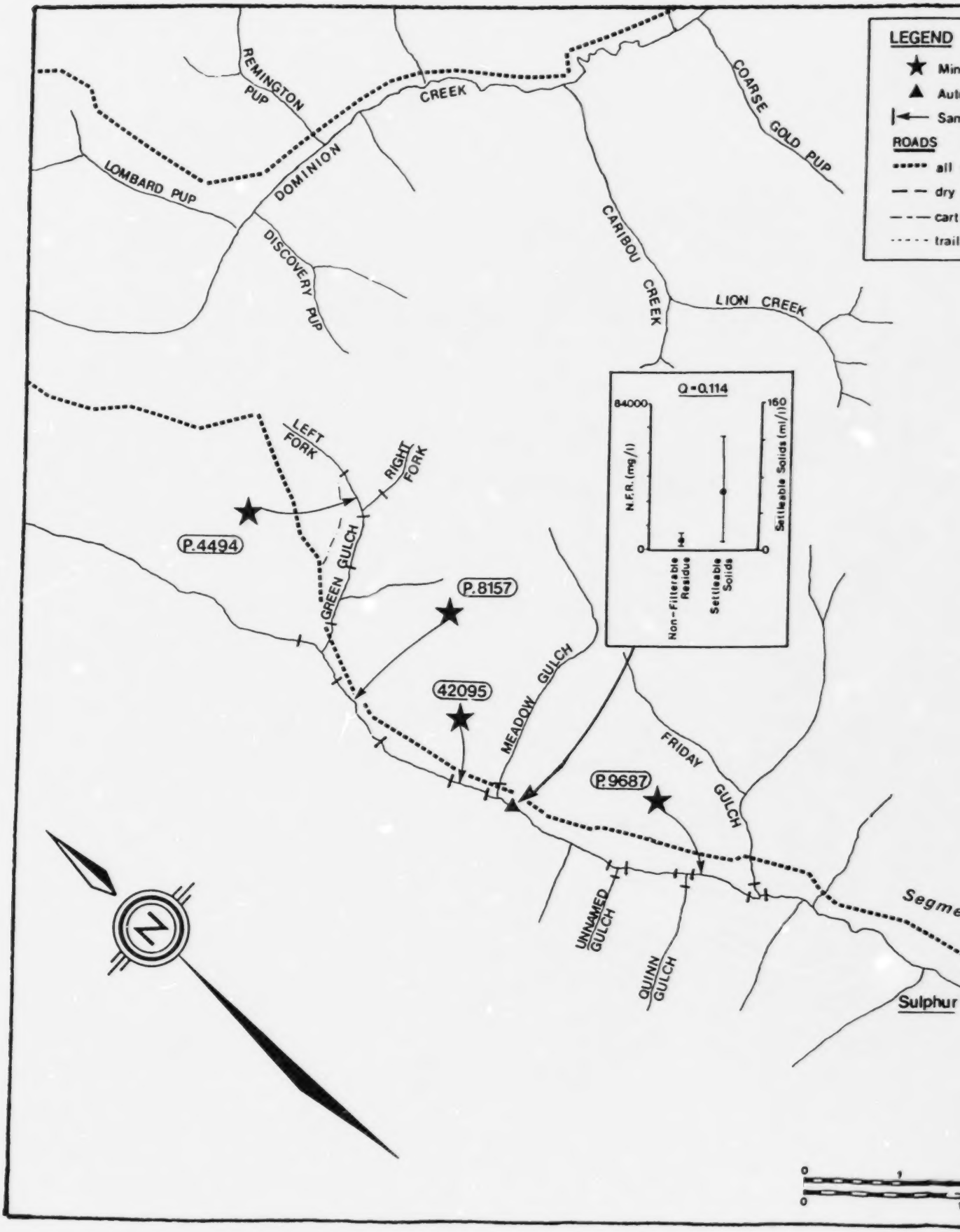
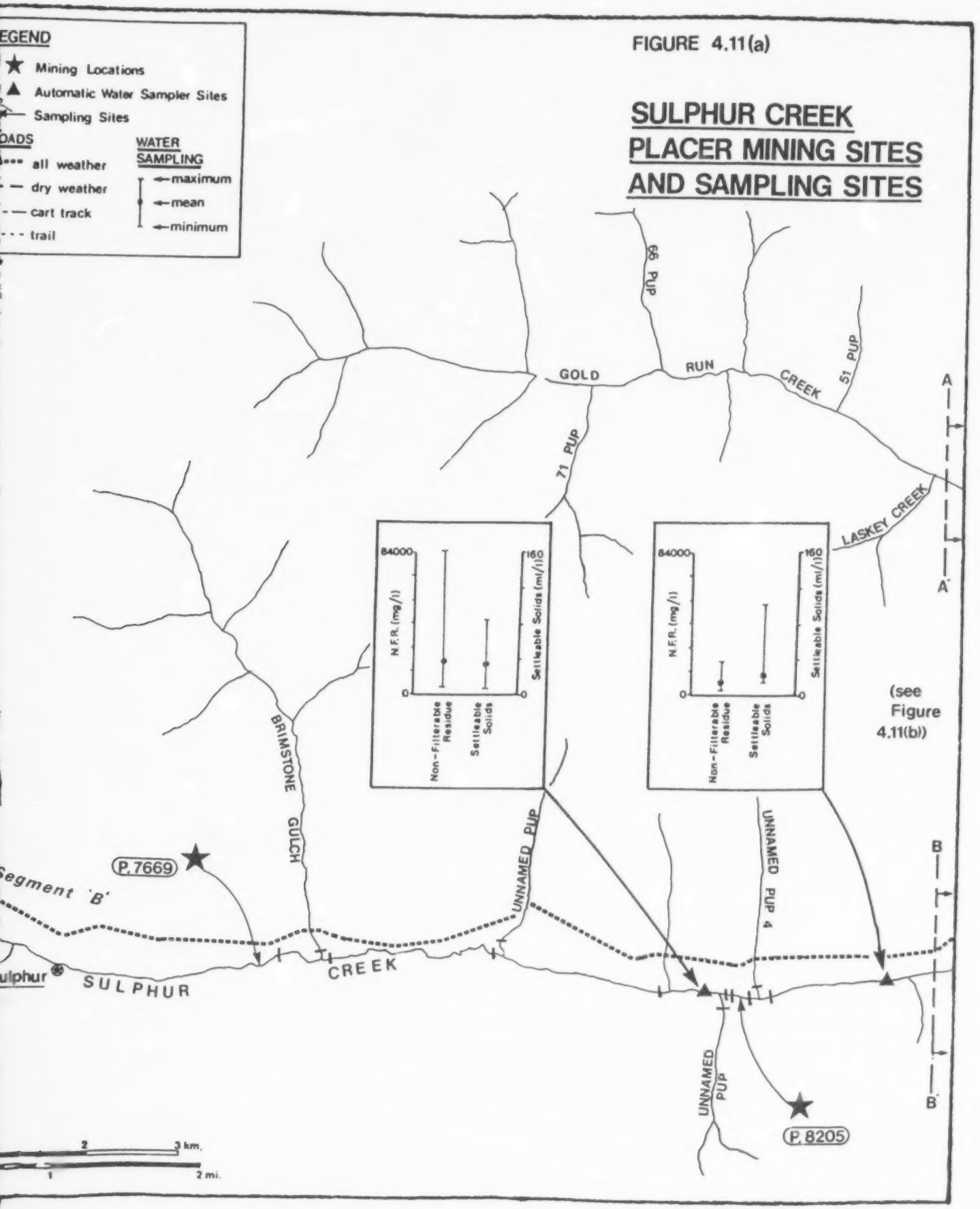

LEGEND
Min
Aut
San
ROADS
all
dry
cart
trail
REMINGTON PUP
CREEK
COARSE GOLD PUP
LOMBARD PUP
DOMINION
CARIBOU CREEK
DISCOVERY PUP
LION CREEK
Q = 0.114
84000
N.F.R. (mg/l)
0
160
Settleable Solids (ml/l)
0
Non-Filterable Residue
Settleable Solids
LEFT FORK
RIGHT FORK
P.4494
GREEN GULCH
P.8157
42095
MEADOW GULCH
FRIDAY GULCH
P.9687
UNNAMED GULCH
QUINN GULCH
Segme
Sulphur
N

FIGURE 4.11(a)

SULPHUR CREEK PLACER MINING SITES AND SAMPLING SITES



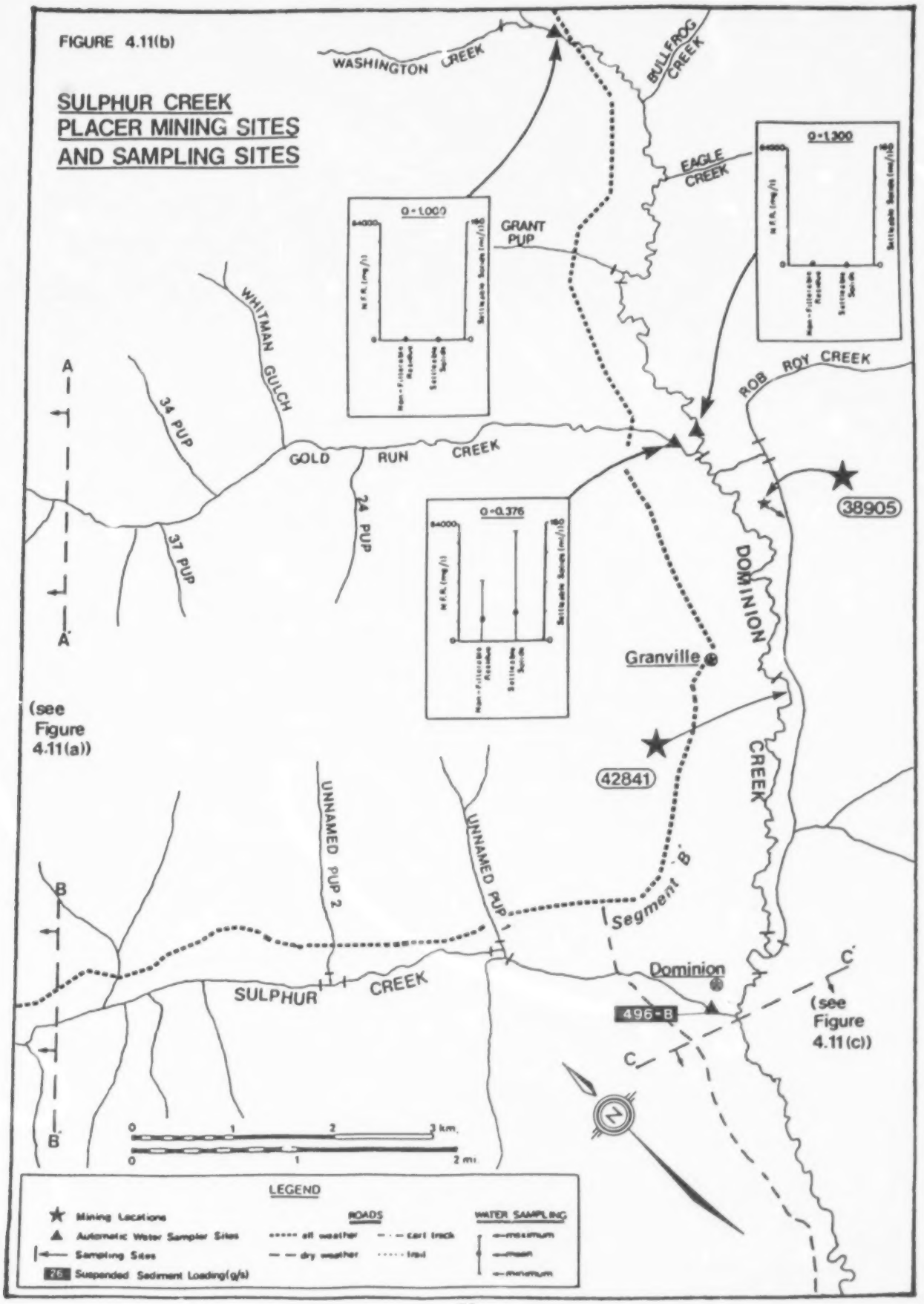


FIGURE 4.11(b)
SULPHUR CREEK
PLACER MINING SITES
AND SAMPLING SITES
WASHINGTON CREEK
BULLFROG CREEK
EAGLE CREEK
GRANT PUP
WHITMAN GULCH
34 PUP
GOLD RUN CREEK
24 PUP
37 PUP
ROB ROY CREEK
DOMINION CREEK
38905
Granville
42841
Segment 'B'
UNNAMED PUP 2
UNNAMED PUP 1
SULPHUR CREEK
Dominion
496-B
(see Figure 4.11(a))
(see Figure 4.11(c))
A
A'
B
B'
C
C'
0-1.000
0-1.300
0-0.376
0 1 2 3 km.
0 1 2 mi.
LEGEND
Mining Locations
Automatic Water Sampler Sites
Sampling Sites
Suspended Sediment Loading(g/s)
ROADS
all weather
dry weather
cart track
trail
WATER SAMPLING
maximum
mean
minimum

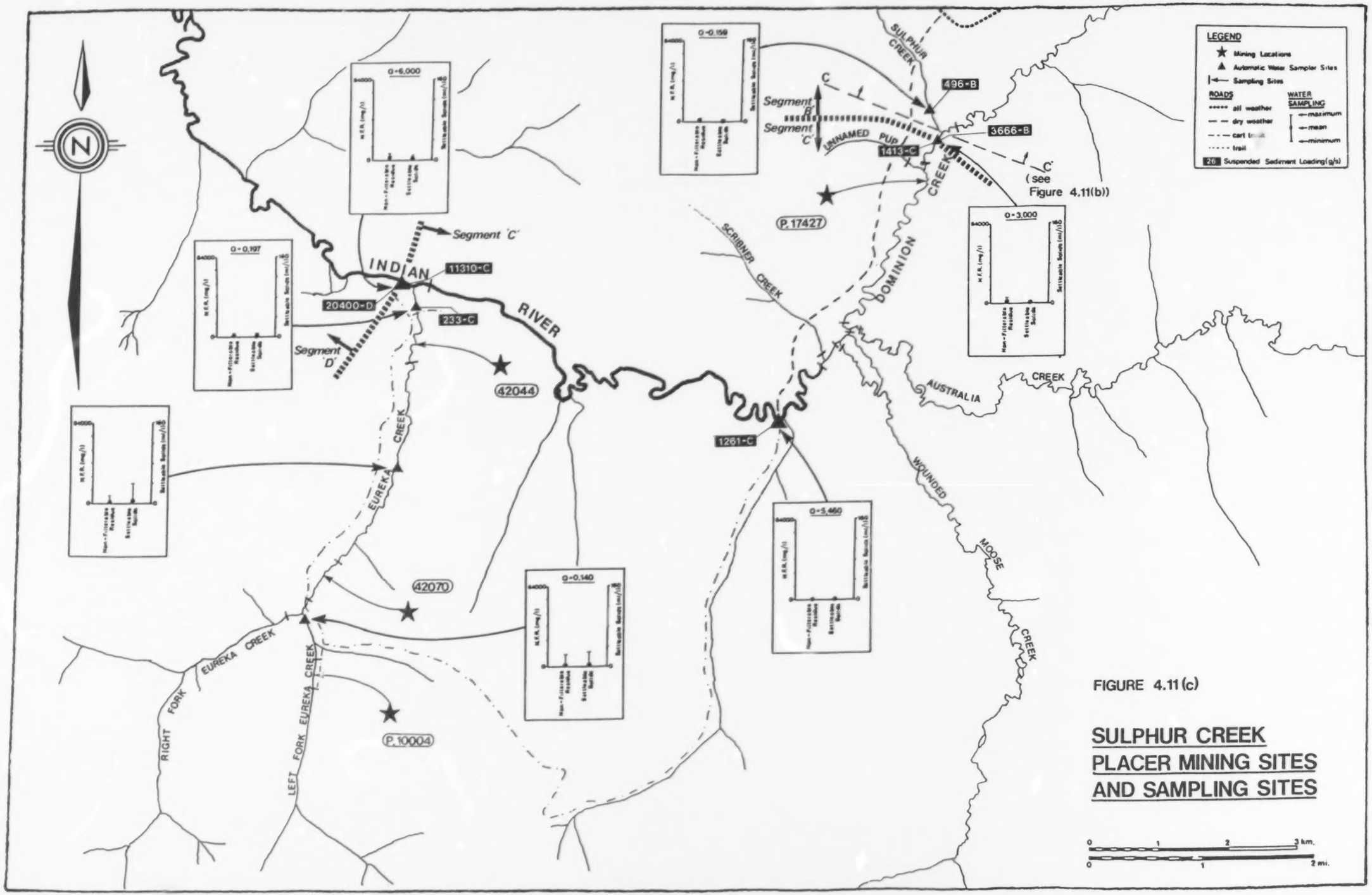


FIGURE 4.11(c)

SULPHUR CREEK PLACER MINING SITES AND SAMPLING SITES

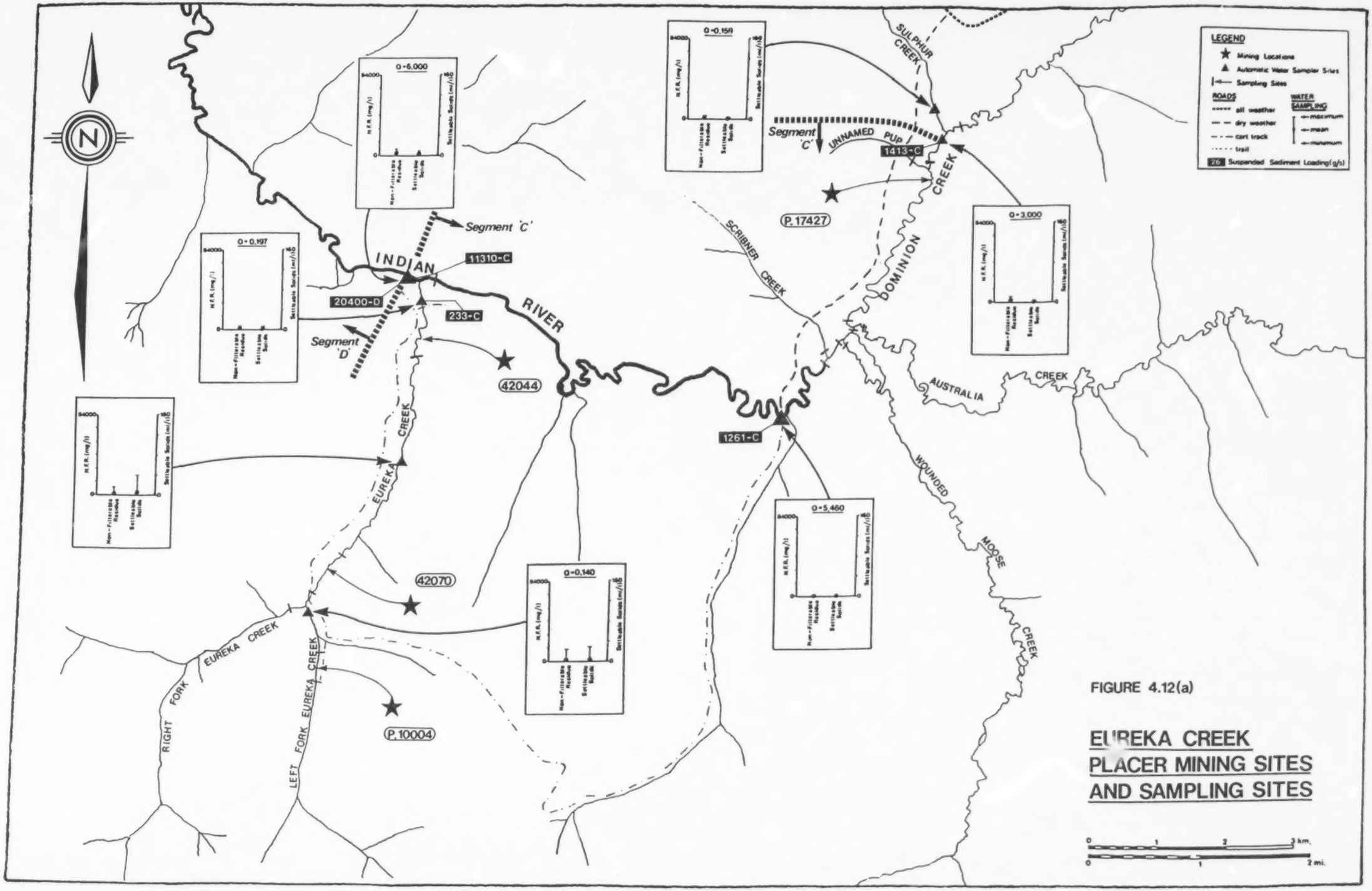


FIGURE 4.12(a)

EUREKA CREEK PLACER MINING SITES AND SAMPLING SITES

FIGURE 4.12(b)

EUREKA CREEK PLACER MINING SITES AND SAMPLING SITES (downstream to Quartz Creek)

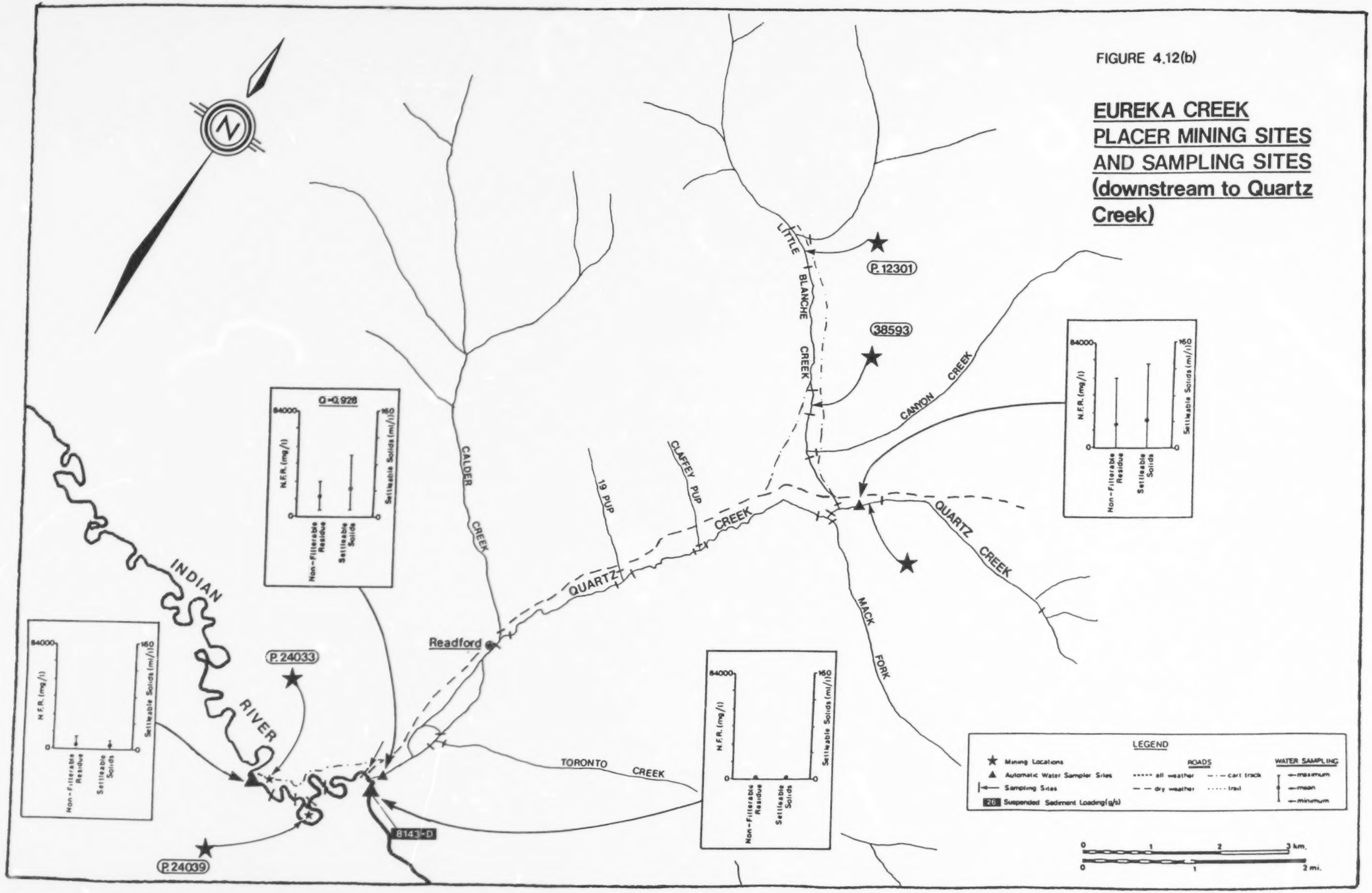


FIGURE 4.13(a)

QUARTZ CREEK PLACER MINING SITES AND SAMPLING SITES

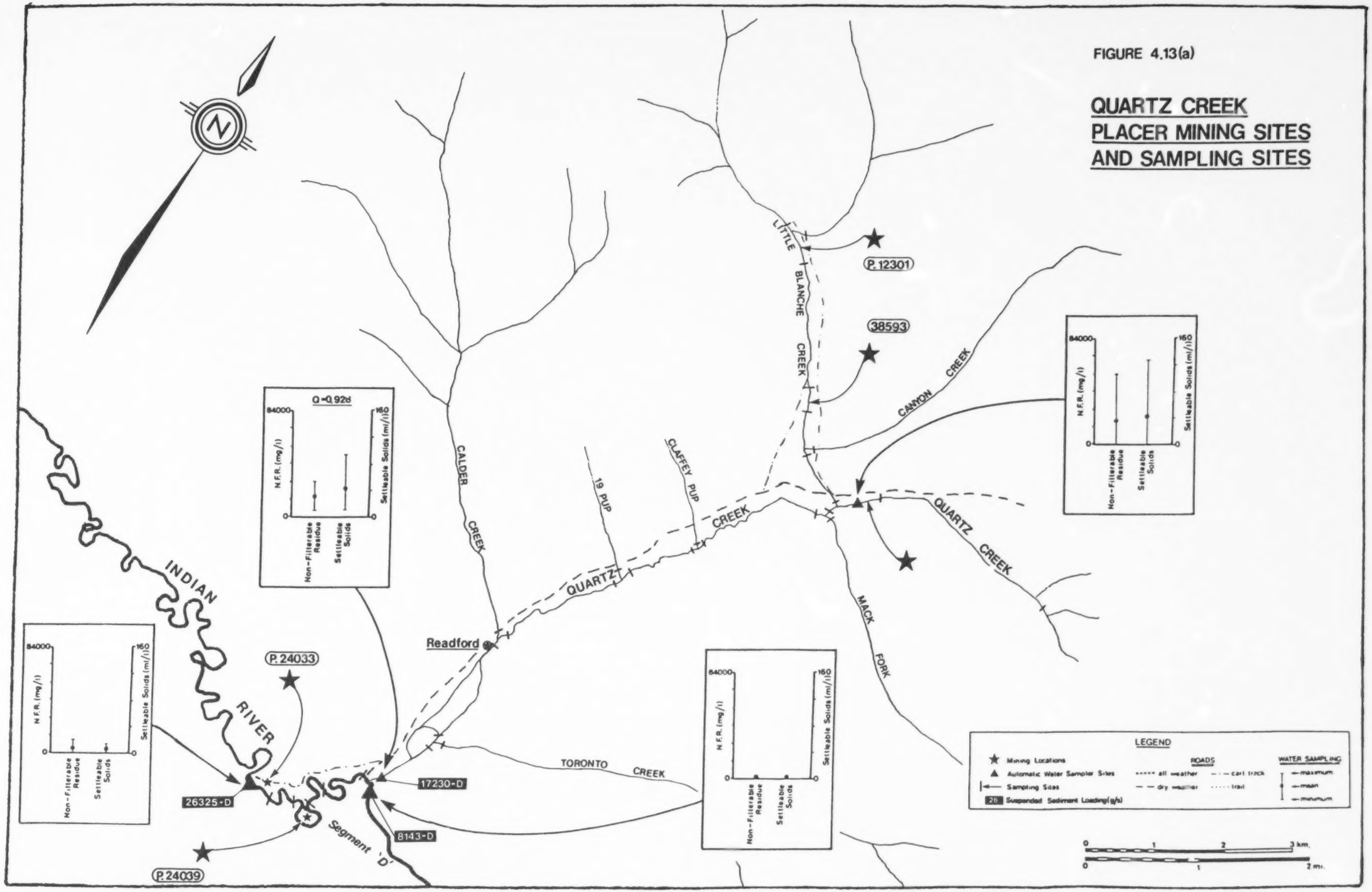


FIGURE 4.13(b)

QUARTZ CREEK PLACER MINING SITES AND SAMPLING SITES

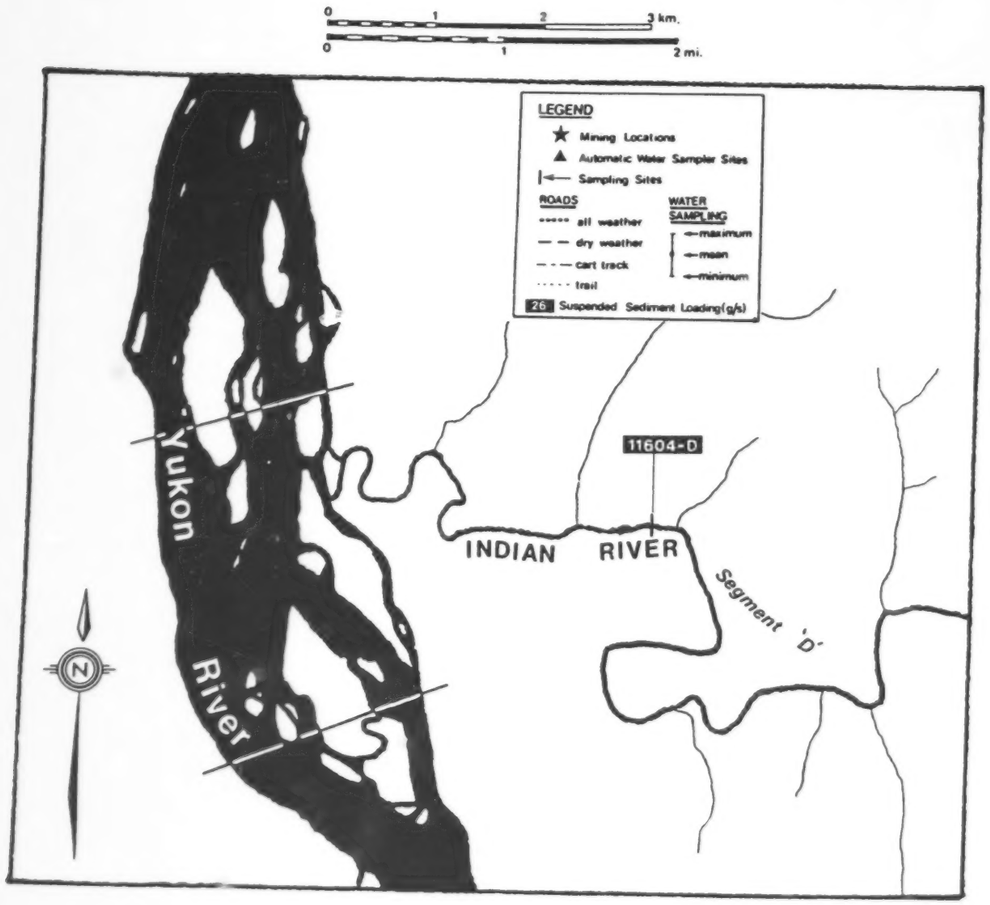


FIGURE 4.14: SOUTH BIG SALMON RIVER

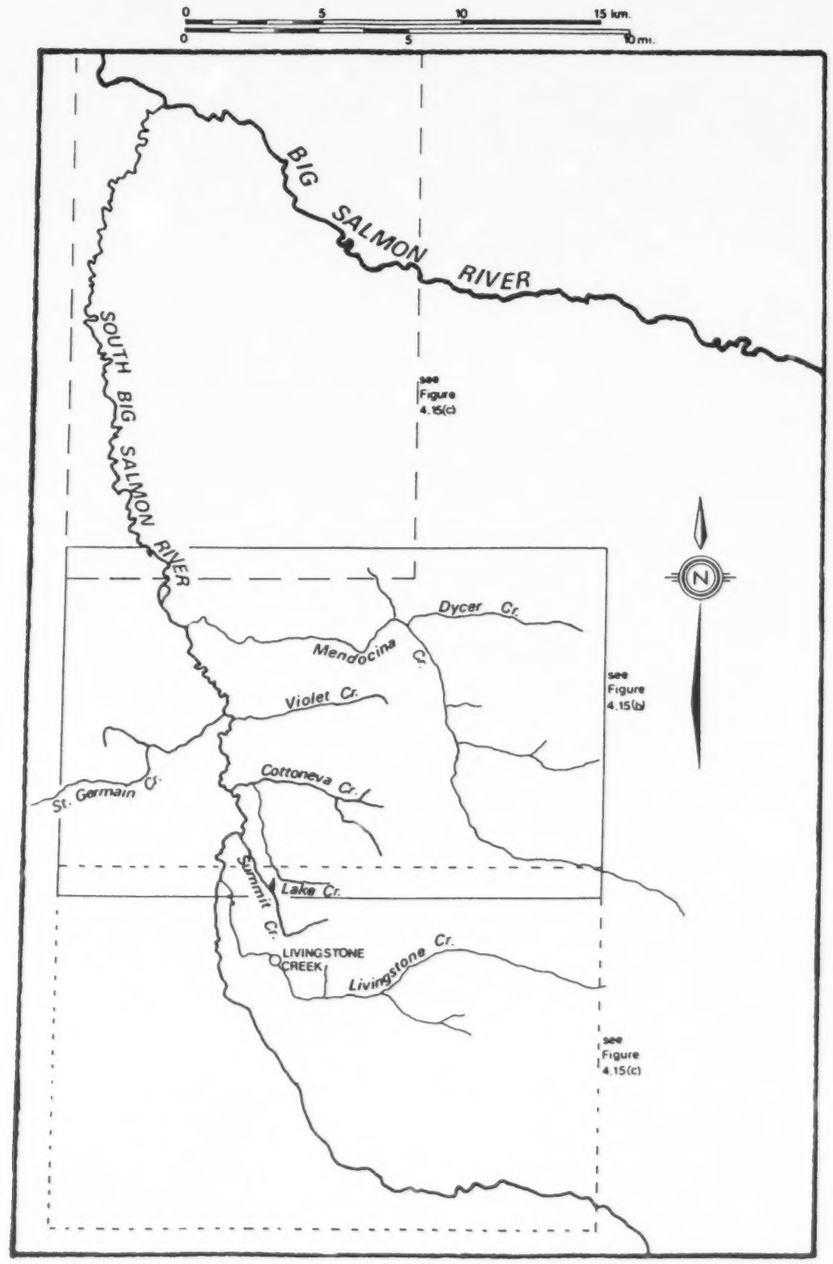
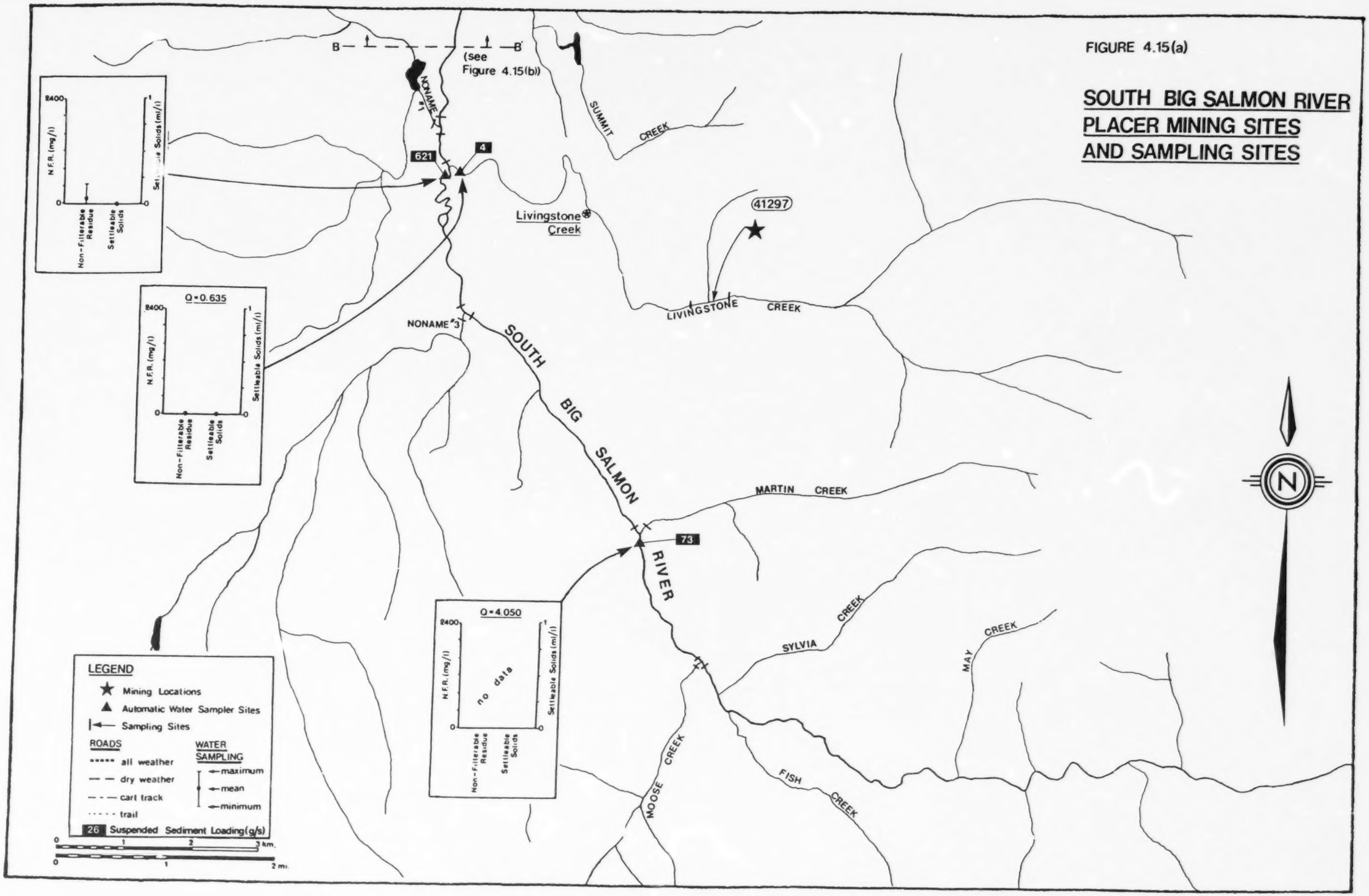


FIGURE 4.15(a)

SOUTH BIG SALMON RIVER PLACER MINING SITES AND SAMPLING SITES



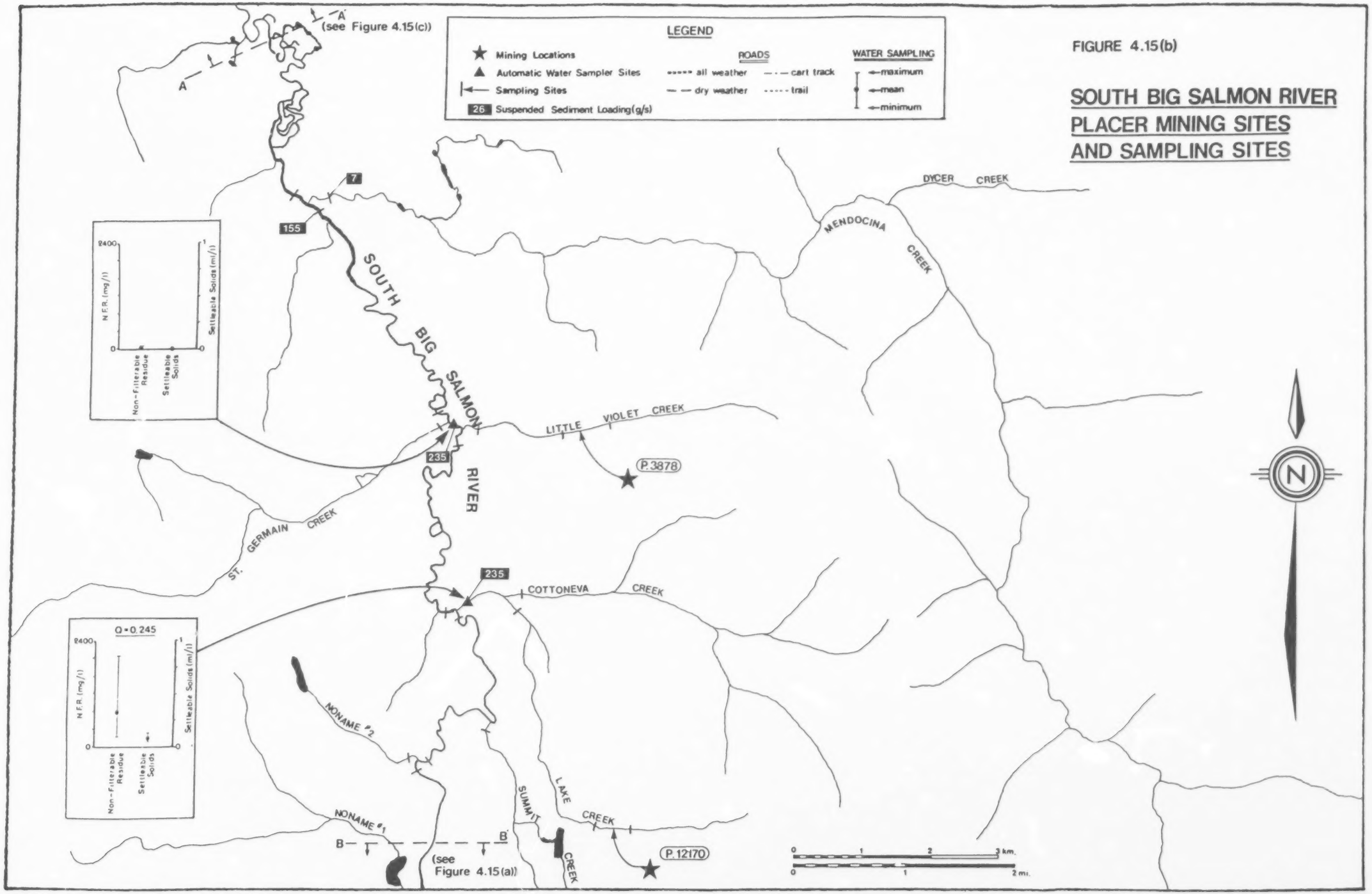


FIGURE 4.15(b)

SOUTH BIG SALMON RIVER PLACER MINING SITES AND SAMPLING SITES

FIGURE 4.15(c)

SOUTH BIG SALMON RIVER PLACER MINING SITES AND SAMPLING SITES